PROPERTIES OF STARCH-BASED PACKAGING FILM INCORPORATED WITH CHITOSAN AND LAURIC ACID AS ANTIMICROBIAL AGENTS

ERARICAR BT SALLEH

UNIVERSITI TEKNOLOGI MALAYSIA

PROPERTIES OF STARCH-BASED PACKAGING FILM INCORPORATED WITH CHITOSAN AND LAURIC ACID AS ANTIMICROBIAL AGENTS

ERARICAR BT SALLEH

A thesis submitted in fulfilment of the
requirements for the award of the degree of
Philosophy Doctor (Bioprocess)

Faculty of Chemical Engineering
Universiti Teknologi Malaysia

JUNE 2011

Specially dedicated to my beloved kids, Nur Era Nabihah bt Zuledham and Muhammad Edham Haziq bin Zuledham. May this achievement inspire them.

ACKNOWLEDGEMENTS

First, thanks to Allah for giving me strength to finish my research study. I would like to express my deepest gratitude to my supervisor, PM Dr. Ida Idayu Muhamad for her invaluable enthusiasm, guidance, patience, encouragement and advice during the entire study. I express my warmest gratitude to PM. Dr. Wan Aizan and Prof. Dr. Azemi sharing their knowledge in this field and for their suggestions and advice.

I am thankful to the whole laboratory staff of Bioprocess Engineering Department for providing technical help, and guidelines throughout the whole research.

I am also owe and very grateful to all my friends especially Norhayati Pa’e, Nozieana Khairuddin, Mahfuzah Mustapha, Nooranis Mustapha, Iryatie Ishak and Norazlina Mohd Nawi. Thank you for always being there for me, to share all the hard time together.

Last but not least, a sincere appreciation goes to my beloved family and all people who involved directly and indirectly for their love and everlasting unconditional support.

ABSTRACT

This study aimed to develop the antimicrobial (AM) packaging based on wheat starch incorporated with chitosan and lauric acid as antimicrobial agents. A series of blends with different ratio of starch, chitosan and lauric acid (S:C:LA) were prepared by casting method. Effects of incorporation of antimicrobial agents into starch-based film were investigated in order to improve the spectrum activity based on measured distributions of inhibitory results. The diffusivity equation approach for describing the antimicrobial effects was also extended to include information on the molecular size of particles in the formed matrices. The Agar Disc Diffusion Assay and Liquid Culture Test measured the distributions of inhibitory effect towards the type of bacterial contamination in terms of Gram-positive, Gram-negative and their combination of wider spectrum activity in the blend films. For the first time, the inhibition size distribution resulting from rationing of base polymers and lauric acid as filler in the starch-base film itself was quantified. Spectrum activity of different Gram-stained bacteria as measured by the bacterial growth inhibition, gave surprisingly consistent pattern on rationing of compositions in the film. This indicates that the spectrum activity produced by the antimicrobial components can be related directly to the ratio on blending during film preparation. This phenomenon is proven by dominating of chitosan (S:C:LA ratio 1:9:0.08 to 3:7:0.24) for 48% increase of effective *E. coli* inhibition (Gram-negative bacteria). More positively, however, it signifies that the affinity of lauric acid towards starch as reported by previous research indicates relatively unambiguously the ratio required to achieve a constant degree of *B. subtilis* (Gram-positive) bacterial inhibition from starch/chitosan/lauric acid dominating of S:C:LA ratio at 4:6:0.32 to 7:3:0.56. Furthermore, S:C:LA ratio 8:2:0.64 and 9:1:0.72 showed good synergic inhibition of 54% higher relative to sole chitosan towards both bacteria. This implies that the ratio index is inherently meaningful, and explains why it has been possible in this work to relate the ratio index directly to a change in physical property of the structural-modified polymer matrices. Further studies of antimicrobial effects investigated the mode of release from the base film. The release of lauric acid in fatty acid food stimulant was satisfactorily expressed by Fickian-diffusion mechanism described by zero order kinetics which indicated that lauric acid released from the film matrix remains constant over time. The physical and mechanical properties of the films were improved relative to sole starch film. Increasing starch amount resulted in progressive interaction and stronger bonding between starch and chitosan molecules nevertheless decreasing the mechanical properties as shown by the results from OTR, WVTR and microstructure studies. S:C:LA ratio 5:5:0.40 gave the most smooth surfaces followed by S:C:LA ratio 6:4:0.48 which confirmed the most homogeneous and dense structure achievable. That is an indicative of a homogeneous and good miscibility or blending of starch and chitosan where SEM, XRD and FTIR analysis confirmed these properties. Results showed that S:C:LA ratio 5:5:0.40 is the phase inversion between S:C:LA ratio dominate by chitosan (S:C:LA ratio 1:9:0.08-4:6:0.32) and S:C:LA ratio dominated by starch (S:C:LA ratio 6:4:0.48-9:1:0.72). These were proven by the SEM, XRD, tensile strength, percent elongation, water uptake, diffusion coefficient, OTR and WVTR results analysis.

ABSTRAK

Penyelidikan ini bertujuan untuk membangunkan pembungkusan makanan antimikrob (AM) menggunakan kanji gandum yang digabungkan dengan kitosan dan asid laurik sebagai agen anti-mikrob. Beberapa siri campuran filem dengan nisbah kanji, kitosan dan asid laurik (S:C:LA) yang berbeza telah disediakan dengan menggunakan kaedah tuangan. Pengaruh penggabungan agen antimikrob dalam filem berasaskan kanji telah diselidiki dalam usaha meningkatkan aktiviti spektrum yang diukur berdasarkan hasil ujian perencatan. Persamaan Keresapan yang telah digunakan untuk menggambarkan kesan antimikrob turut digunakan untuk mendapat maklumat tentang saiz molekul zarah dalam matriks yang terbentuk. Ujian Peresapan Agar dan Ujian Kultur Cecair dijalankan bagi mengukur kesan perencatan terhadap jenis bakteria pencemar Gram-positif, Gram-negatif dan gabungan keduanya untuk aktiviti spektrum yang lebih luas dalam campuran filem. Untuk pertama kalinya, taburan saiz perencatan kesan daripada penisbahan polimer asas dan asid laurik sebagai pengisi dalam filem berasaskan kanji telah diukur. Menariknya, spektrum aktiviti bakteria dengan Gram berbeza yang diukur melalui pemerhatian terhadap perencatan pertumbuhan bakteria, memberi pola yang konsisten pada komposisi penisbahan dalam filem. Hal ini menunjukkan bahawa aktiviti spektrum yang dihasilkan oleh komponen antimikrob boleh dikaitkan secara langsung dengan nisbah campuran penyediaan filem. Fenomena ini terbukti dengan dominasi kitosan (nisbah S:C:LA 1:9:0.08 hingga 3:7:0.24) dengan kenaikan 48% bagi keberkesanan perencatan *E. coli* (bakteria Gram-negatif). Bagaimanapun, itu menandakan bahawa afiniti asid laurik terhadap kanji seperti yang dilaporkan oleh kajian sebelumnya yang relatif jelas menunjukkan nisbah yang diperlukan untuk mencapai tahap malar *B. subtilis* (Gram-positif) perencatan bakteria dari kanji/kitosan/asid laurik mendominasi S:C:LA pada nisbah 4:6:0.32 sehingga 7:3:0.56. Selanjutnya, nisbah S:C:LA 8:2:0.64 dan 9:1:0.72 menunjukkan perencatan yang baik iaitu 54% lebih tinggi berbanding dengan kitosan sahaja terhadap kedua-dua bakteria. Ini bermakna bahawa indeks nisbah memberi kesan secara semulajadinya dan menjelaskan bagaimana kajian ini dapat mengaitkan indeks nisbah dengan perubahan ciri-ciri fizikal struktur matriks polimer terubahsuai. Penelitian lebih lanjut terhadap kesan antimikrob telah menyelidiki cara pembebasan dari filem asas. Pembebasan asid laurik dalam bahan yang merupai makanan yang mengandungi asid lemak sebenar dapat diungkapkan menggunakan mekanisme Peresapan Fickian yang digambarkan oleh susunan kinetik sifar yang menunjukkan bahawa asid laurik dilepaskan dari filem matriks adalah malar dari masa ke masa. Sifat fizikal dan mekanik dari filem-filem meningkat berbanding filem yang mengandungi kanji sahaja. Peningkatan jumlah kanji menghasilkan interaksi progresif dan ikatan yang kuat antara molekul kanji dan kitosan namun sifat mekanik menurun seperti yang diperolehi dalam keputusan OTR, WVTR dan kajian mikrostruktur. Nisbah S:C:LA 5:5:0.40 adalah permukaan yang paling halus diikuti oleh nisbah S:C:LA 6:4:0.48 membuktikannya sebagai campuran yang paling homogen dan padat. Ini menjadi penunjuk kehomogenan dan percampuran yang baik antara kanji dan kitosan di mana SEM, XRD serta analisis FTIR mengesahkan sifat-sifat ini. Hasil kajian menunjukkan bahawa nisbah S:C:LA 5:5:0.40 adalah fasa pembalikan antara nisbah S:C:LA yang didominasi oleh kitosan (nisbah S:C:LA 1:9:0.08-4:6:0.32) dan S:C:LA yang didominasi oleh kanji (nisbah S:C:LA 6:4:0.48-9:1:0.72). Keadaan ini dapat dibuktikan dari hasil analisis SEM, XRD, kekuatan tegangan, peratus pemanjangan, penyerapan air, pekali penyerapan, OTR dan WVTR

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

AM	-	Antimicrobial
ASTM	-	American society for testing and materials
ANOVA	-	Analysis of variance
B. subtilis	-	*Bacillus subtilis*
BHA	-	Butylated hydroxyanisole
BHT	-	Butylated hydroxytoluene
CO_2	-	Carbon dioxide
D	-	Diffusion coefficient
DD	-	Degree of deacetylation
DSC	-	Differential scanning calorimetry
E	-	Percent of elongation
E. coli	-	*Escherichhia coli*
EDTA	-	Ethylene diamine tetraacetic acid
EPA	-	Environment protection agency
EVOH	-	Ethylene vinyl alcohol
FDA	-	Food and drug administration
FTIR	-	Fourier transform infrared spectrometry
FESEM	-	Field-emission scanning electron microscope
GRAS	-	General recognize as safe
GNP	-	Gross national product
HDPE	-	High density polyethylene
HPLC	-	High performance liquid chromatography
IR	-	Infra-red
LA	-	Lauric acid
LDPE	-	Low density polyethylene
MC	-	Moisture content
NH_2	-	Amino

NH_3	-	Ammonia
O_2	-	Oxygen
OD	-	Optical density
OH	-	Hydroxide
OTR	-	Oxygen transfer rate
PE	-	Polyethylene
PET	-	Polyethylene terephthalate
PS	-	Polystyrene
PVOH	-	Polyvinyl alcohol
RH	-	Relative humidity
SAS	-	Statistical analysis system
S:C:LA	-	Starch:Chitosan:Lauric Acid
SEM	-	Scanning electron microscope
TBHQ	-	Tert-butylhydroquinone
TS	-	Tensile strength
TFA	-	Trifluoroacetic acid
TSB	-	Tryptic soy broth
UHT	-	Ultra high temperature
USDA	-	United stated department of agriculture
UTS	-	Ultimate tensile strength
UV	-	Ultra-violet
VP	-	Variable pressure
WVTR	-	Water vapour transmission rate
WVP	-	Water vapour permeability
XRD	-	X-ray diffraction
Y	-	Modulus young’s

LIST OF SYMBOLS

M_i	-	Initial weight of the sample before drying
M_f	-	Final weight after drying
L	-	Thickness of the sample
M_t	-	Moisture content at time t
M_∞	-	Moisture content at the equilibrium
k	-	Rate constant of zero order
n	-	Release component
σ	-	Tensile stress
ε	-	Tensile strain
E	-	Young modulus
X (t)	-	Cell concentration
μ	-	Specific growth
t	-	Time

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Introduction

Foods, unlike durable goods such as electronics and furniture, are usually perishable products and heterogeneous mixtures. In addition, foods have safety aspects and relatively very short shelf life. Therefore the food packaging is quite different from the packaging of durable products (Han, 2000). The food product may include processed foods, beverage, fresh produce or minimally processed fruits and vegetable at the food market. Most food product are packaged for distribution convenience and quality management, and usually opened at the point of consumption. Foods are the first major product among all of packaged products in market, and food industry is the biggest end-user of most kinds of packaging materials (Han, 2003).

The basic functions of food packaging are protection, containment, information and convenience. Packaging is the one most important element in the preservation of products for storage, transportation and end use. Common packaging materials are paper/paperboard, glass, metals and plastics.

The first priority of food packaging criteria is always food safety. Food safety is one of the key issues of public health. Food deterioration always relates to the food safety as well as simple quality maintenance. Contaminated materials and inferior light package would deteriorate food quality and jeopardize public health.

Hence food safety is the essential issue of the purpose of food packaging. Microbial protection and preservation are characteristic functions of food packaging compared to other packaging such as hardware and appliance (Han, 2003). One option is to use packaging to provide an increased margin of safety and quality. In line with that, active packaging technologies are being developed as a result of these driving forces.

1.2 Active Packaging

Active packaging is an innovative concept that can be defined as a mode of packaging in which the package, the product and the environment interact to prolong shelf life or enhance safety or sensory properties, while maintaining the quality of the product (Suppakul *et al.*, 2003). This is particularly important in the area of the fresh and extended shelf life foods as originally described by Labuza and Breene (1989).

Floros *et al.* (1997) reviewed the products and patents in the area of Active Packaging and identified antimicrobial packaging as one of the most promising versions on an Active Packaging system. Other forms of active packaging are oxygen scavenging, ethylene scavengers, carbon dioxide scavengers and emitters, moisture regulators, antioxidant release and release or absorption of flavours and odours.

Active packaging was introduced in the market in 70's in Japan (oxygen scavenging sachets-Mitsubishi Gas Chem. Corp.). Interest in EU and US rose in 1990's. There was high expectation of growth in active packaging in EU and US during 2000's. An overview of the market demand on active packaging can be seen from Figure 1.1 and Table 1.1.

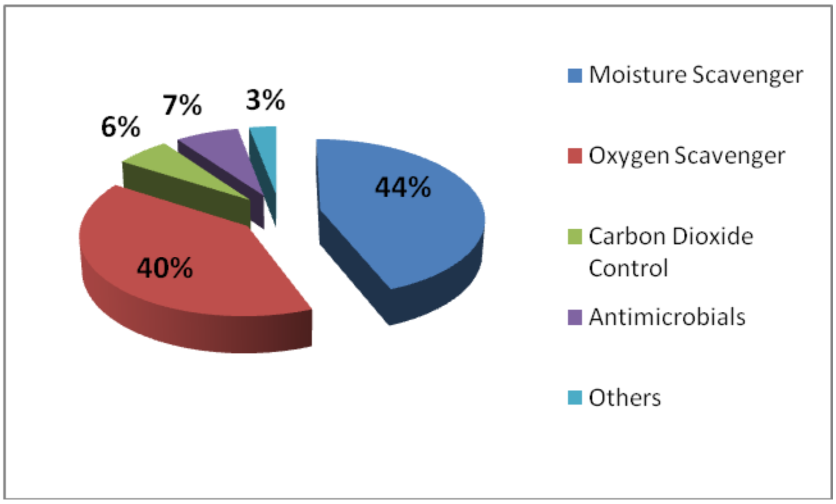

Figure 1.1: Type of active packaging in 2002 (total of $1371 millions) (Source of all data: Pira International Ltd. (www.pira-international.com.)).

Table 1.1: Global market for active packaging by type, 2001-2010 (Source: Pira International (www.pira-international.com.)).

	$ million			% share 2005	% change	
	2001	**2005**	**2010**		**2001-2005**	**2005-2010**
Oxygen Scavenger	371	660	985	37	15.5	8.3
Carbon Dioxide Scavenger	81	108	156	6	7.6	7.6
Ethylene Scavenger	30	57	100	3	17.4	11.9
Antimicrobial Films	50	100	170	6	18.9	11.2
Ethanol Emitters	21	37	65	2	15.2	11.9
Moisture Scavenger	190	287	405	16	10.9	7.1
Odour Absorbers	28	47	70	3	13.8	8.3
Antioxidants	3	7	20	0	23.6	23.4
Self venting	195	280	550	16	9.5	14.5
Susceptor laminates	80	165	265	9	19.6	9.9
Temperature Control	15	38	100	2	26.2	21.4
Total Above	1064	1786	2556	100	13.8	10.1
*Notes: Total mat not add up due to rounding						

Active packaging continues to be developed and to find some commercial applications. In the food and beverage market, growth of active packaging concepts is being driven by the growing use of packaged food, increasing demand for ready-prepared foods such as microwave meals, and increasing use of smaller package sizes. Drivers include consumer desires for food safety, quality, freshness and convenience as well as packaging user's desire for increased shelf-life. Active packaging is used more heavily in Japan, but use in Europe and North America is beginning to increase as shown in Figure 1.2.

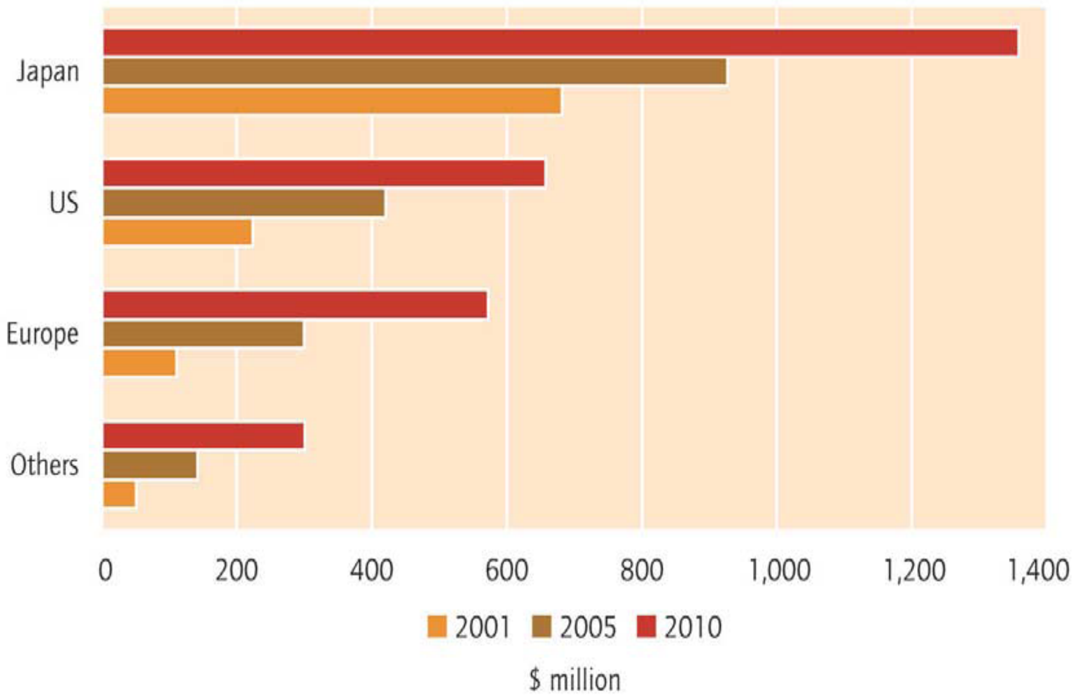

Figure 1.2: Global markets for active packaging 2001-2010. (Source: Pira International Ltd. (www.pira-international.com.)).

1.3 Antimicrobial (AM) Packaging

Recently antimicrobial packaging has emerged one of the most reliable and promising tool in the search of 'active' packaging (Brody, 2001; Salleh *et al*., 2007; Dutta *et al*., 2009 ; Tripathi *et al*., 2010). Antimicrobial packaging is one of the most promising active packaging systems that have been found highly effective in killing or inhibiting spoilage and pathogenic microorganisms that contaminate foods (Salleh *et al*., 2007). Contamination of food products by pathogenic bacteria has emerged as a serious public concern. Bacteria such as *Bacillus cereus* and *Escherichia coli* are identified as serious and most frequently occurring food-borne pathogens associated with food-borne illness. Others are *Listeria monocytogenes*, *Staphylococus aureus*, *Salmonella typhimurium* and *Shigella sonnei* (Kandasamy, 2005). Antimicrobial packaging is one promising approach to prevent both contamination of pathogens and growth of spoilage microorganisms on the surface of food. Antimicrobial food packaging acts to reduce inhibit or retard the growth of microorganisms that may be present in the packed food or packaging material itself (Appendini and Hotchkiss, 2002). According to Han (2003a), antimicrobial function of the packaging system can be achieved by incorporating active substances into the packaging system by various ways. The antimicrobial packaging is conducted by (1) the addition of antimicrobial containing sachets or pads into food packages; (2) the coating, immobilization or direct incorporation of antimicrobials into food packaging materials or (3) the use of packaging materials that are inherently antimicrobial (Apendini and Hotchkiss, 2002).

1.3.1 Biodegradable and Active Packaging

Nowadays, about 150 million tons of plastic are produced annually all over the world, and the production and consumption continue to increase (Parra *et al*., 2004). Most of these plastics are crude oil based, as the price of oil and natural gas has risen, manufacturing cost of plastic will become more expensive.

In addition, handling of plastic waste are associated with serious environmental pollution problem due to waste disposal and undegradedable polymers. Therefore, the use of agricultural biopolymers that are easily biodegradable not only would solve these problems, but would also provide a potential new use for surplus farm production (Okada, 2002; Pavlath and Robertson, 1999; Scott, 2000). Because of the environmental concerns and technological problems such as denaturing effects of thermal polymer processing methods, extrusion and injection moulding, the incorporation of bio preservatives into biodegradable films is more suitable than incorporation into plastic films (Appendini and Hotchkiss, 2002; Han, 2000; Suppakul *et al*., 2003). Direct addition of antimicrobial substances into food formulations or onto food surfaces may not be sufficient to prevent the growth of pathogenic and spoilage microorganisms as antimicrobial substances applied could be partially inactivated or absorbed by the food systems (Ouattara *et al*., 2000). Until now, the edible and biodegradable bio-based films are always not meant to totally replace the conventional packaging materials. However, the use of active bio-based films as packaging materials is still one of the most promising ways for effective methods of maintaining food quality (Aider, 2010).

Most of biodegradable films are edible and their film formations occur under mild conditions. Different edible films incorporated with bio preservatives include cellulose derivatives, carrageenan, alginate, protein films include casein, collagen, corn zein, gelatin, soy protein, whey proteins and wheat gluten (Padgett *et al*., 1998; Cha *et al*., 2002; Han, 2000; Quintavalla and Vicini, 2002; Suppakul *et al*., 2003).

In the food packaging sector, biodegradable polymers based on natural polysaccharides, particularly starch has gain more attention owing to its availability as agricultural surplus raw material, abundant, can be produced at low cost and at large scale, nonallergic and thermoprocessibility. Several studies are concentrated on the development of starch-based materials for the above-mentioned reasons.

According to Narayan (2001), starch based materials reduce non-renewable resources use and environmental impact associated with increasing emissions as CO_2 and other products. Starches are polymer that naturally occurs in a variety of botanical sources such as wheat, corn, yam, potatoes and tapioca. Starches can interact with many additives or components of the food (Famá *et al*., 2005). However starch presents some major drawbacks such as the strong hydrophilic behaviour (poor moisture barrier) and poorer mechanical properties than the conventional non-biodegradable plastic films used in the food packaging industries.

In the last years much research has been focused on the use of biodegradable films as a way of supporting antimicrobials in food products. Several researchers have previously reported on coating food contact surfaces with antimicrobial compounds. Various natural and synthetic compounds are being used to produce antimicrobial films for foods; some of them include metallic ions, organic acids, benzoates, sorbets, fatty acid, polysaccharides and bacteriocins (Santiago-Silva *et al*., 2009).

In Japan, chemical antimicrobial agents Ag-substituted zeolite is the most common antimicrobial agent incorporated into plastics. Ag-ions which inhibit a range of metabolic enzymes have strong antimicrobial activity. Unfortunately Ag-zeolite is expensive, and it is laminated as a thin layer containing Ag-zeolite. Only a few descriptions of the effectiveness of this material have appeared and the regulatory status on the addition of Ag to food has not been clarified in the US or Europe (Vermeiren *et al*., 1999). Several other chemical compounds have been proposed and/ or tested for antimicrobial activity in food packaging including organic acids such as sorbet, propionate and benzoate. Sodium benzoate, sodium nitrate, potassium sorbet and sodium lactate were incorporated into synthetic plastic, LDPE, PS and PET. Sodium nitrate inhibit *Aspergillus niger* and *Bacillus subtilis*, sodium benzoate and potassium sorbet had activity only against *B. subtillis* and sodium lactate did not have any antimicrobial activity as reported by Vartiainen *et al*. (2003).

Due to the health concern of consumers especially concern over the safety of the food and so the demand for natural foods has spurred the search for bio preservatives and this affect the packaging industry to show greater interest in the use of bio preservatives for antimicrobial packaging. For the consumer, it seems safer when active agents are indirectly integrated in the food package. Moreover, consumers tend to accept products to which naturally occurring substances have been added more than those containing synthetic agents. This trend subsequently draws many researchers to integrate natural antimicrobial into food packaging materials agents (Salleh *et al*., 2009). Natural compounds, such as essential oils, chitosan, nisin or lysozyme, are investigated to replace chemical preservatives and to obtain “green label’ products (Devlieghere *et al*., 2004). Nisin and lauric acid are two food-grade antimicrobials shown to be effective in food applications.

Dawson *et al*. (2002) incorporated lauric acid and nisin singly and together into thermally compacted soy films. Nisin and lauric acid films were equally effective in reducing *L. monocytogenes* in 1% peptone water after 48h exposure. However, the combination of nisin and lauric acid in corn zein cast films was found to be more effective in reducing *L. monocytogenes* in peptone water than when each used singly (Hoffman *et al*., 2001). The activity of bacteriocins is however often limited due to its narrow activity spectrum (Devlieghere *et al*., 2004).

Besides, Padgett *et al*. (2000) revealed that addition of 8% lauric acid into corn zein films significantly lowered the film water permeability. In addition to that, chitosan inherent antimicrobial reaction against a wide range of microorganisms such as filamentous fungi, yeast and bacteria (Fernandez *et al*., 2008). Chitosan has already been proved as a food additive in some countries, for instance in Japan and Korea (KFDA, 1995). Furthermore, this polymer also presents interesting properties such as excellent film-forming capacity and gas and aroma barrier properties at dry conditions, which makes it a suitable material for designing food coatings and packaging structures (Caner, 2005). The advantage in having a film material carrying a biocide is that continued inhibition can occur during storage or distribution of the food product.

1.4 Significance of the Study

Throughout history, mankind has been striving to improve the safety and stability of food. It began in an empirical way with a few simple processes such as smoking and salting. Now a precise science and modern food technologists have a wide range of preservative compounds at their disposal. Despite the undoubted benefits, however, there are concerns over the long-term health effects of many food preservatives in use today. Modern consumers are increasingly concerned about the health implications (be the real or imagined) of the foods they eat, as evidenced by the growing trend for additive-free and organic produce.

There is, thus, both a commercial and a public health incentive to develop novel natural antimicrobial systems for use in foods and food-related applications, and reduce dependency on traditional preservatives. Worldwide, considerable research effort is dedicated to achieving this objective (Rhoades and Rastall, 2000).

The term antimicrobial packaging encompasses any packaging technique(s) used to control microbial growth in a food product. These include packaging materials and edible films and coatings that contain antimicrobial agents and also techniques that modify the atmosphere within the package. In recent years, antimicrobial packaging has attracted much attention from the food industry because of the increase in consumer demand for minimally processed, preservative-free products. Reflecting this demand, the preservative agents must be applied to packaging in such way that only low levels of preservatives comes into contact with the food.

The film or coating technique is considered to be more effective, although slightly complicated to apply. New antimicrobial packaging materials are continually being developed. Many of them exploit natural agents to control common food-borne microorganisms. Current trend suggest that, in due course, packaging will generally incorporate antimicrobial agents, and the sealing systems will continue to improve. Unfortunately, all antimicrobial agents have different activities which affect microorganisms differently. There is no ‘Magic Bullet’ antimicrobial agent effectively working against all spoilage and pathogenic microorganisms. This is due to the characteristic antimicrobial mechanisms and due to the various physiologies of the microorganisms.

The focus of packaging in the past has been on the appearance, size and integrity of the package. A greater emphasis on safety features associated with the addition of antimicrobial agents is the current area for development in packaging technology.

1.5 Research Problem

A widespread trend worldwide is the movement towards "natural" food products. In meeting this demand, there has been increased interest in the food industry in using antimicrobial preservatives that are perceived as more natural. Future work will focus on the use of biologically active derived antimicrobial compounds bound to biopolymers. However many natural antimicrobials have a limited spectrum of activity and are effective only at very high concentrations. The need for new antimicrobials with wide spectrum activity and low toxicity will increase. A possible solution may be using combinations of antimicrobials (Sofos *et al*., 1998). Instead of concentrating on development of new antimicrobial, it seems potentially practical to combine the antimicrobial agents that already being researched.

Lauric acid, a medium length- long chain fatty acid is found in the form of glycerides in a number of natural fats, coconut oil and palm-kernel oil. It offers advantages in food processing as it acts as a kind of preservative, staving off oxidation and spoilage. Lauric acid has been shown to have an antimicrobial effect against Gram-positive bacteria and yeasts (Beuchat and Golden 1989; Kabara 1993).

Beuchat and Golden (1989) suggested that fatty acids were bacteriostatic and may be potential microbial inhibitors in foods using a systematic approach with other antimicrobials. Based on Padgett *et al*. (2000), Nisin instantaneously kills *L. plantarum* cells whereas lauric acid inhibits more slowly but steady inhibitory effect. Furthermore, the incorporation of lipid compounds such as fatty acid to a starch film decreases the moisture transfer due to their hydrophobic properties (Coma *et al*., 2001). Fatty acids, such as lauric acid were found to be effective in limiting water vapour transfer through edible films (Gennadios *et al*., 1993; Greener and Fennema, 1989 a, b; Kamper and Fennema, 1984; Kester and Fennema, 1989).

A packaging material with a wide antimicrobial spectrum would be necessary and desirable for universal use to improve the storage stability of variety of foods.

For this purpose, the incorporation of another antimicrobial agent into the packaging materials would be useful (Lee *et al.*, 2004b). Besides, the use of chitosan in preparing the antimicrobial packaging films was based on the fact that it has good film forming properties. Ban *et al*. (2006) reported that chitosan can also play an important role in the enhancement of starch-based film strength. However, considering the cost of chitosan preparation, it seems important to combine it with other films forming biopolymers such as polysaccharides (Aider, 2010).

Chitosan, a polysaccharide of β-1,4 linkage and a deacetylated form of chitin, appears as a natural antimicrobial candidate due to their non-toxicity (Hirano *et al*., 1994), biocompatibility (Muzzarelli, 1993), biodegradability (Shigemasa *et al*., 1994), film forming ability (Averbach, 1978) and inherent antimicrobial properties (Sudarshan *et al*., 1992). Chitosan can inhibit the growth of a wide variety of fungi, yeasts and bacteria (Rhoades and Rastall, 2000; No *et al*., 2003; Tsai *et al*., 2002; Sagoo *et al*., 2002). It was also reported that both Gram-positive and Gram-negative bacteria were inhibited by those antimicrobial films when chitosan was incorporated into low-density polyethylene (LDPE) film at concentrations above 1.43% (Park *et al*., 2002). Moreover, antimicrobial properties of chitosan can be enhanced by synergistic enhancement with antimicrobial agents (Lee *at al*., 2004b) or in combination with other hurdle technologies. Besides the reasons for chitosan addition in this study are the good film forming, having antimicrobial activity, have a selective permeability to gases (CO_2 and O_2) and good mechanical properties (Bangyaken *et al*., 2006; Mathew and Abraham, 2008; Chillo *et al*., 2008; Vargas *et al*., 2009). However, the fact that they are highly permeable to water vapour limits their uses which are an important drawback. An effective control of moisture transfer is a desirable property for most foods but yet chitosan still relatively more hydrophobic nature than starch that could provide higher moisture barrier and water resistance (Vargas *et al*., 2009).

Starch produces film with good mechanical properties and coverings that are efficient barriers against low polarity compounds. However, they do not offer good barrier against humidity (Azeredo *et al*., 2000; Kester and Fennema, 1989). The application of hydrophilic films such as starch-based films is limited by the water solubility and the poor water vapour permeability. To solve this shortcoming, the blending of starch with different bio-polymers (Xu *et al*., 2005; Chillo *et al*., 2008) or the addition of hydrophobic materials such as oils, waxes and fatty acid have been proposed (Garcia *et al*., 2000; Ayranci and Tunc, 2003; Chillo *et al*., 2008).

The release rate of antimicrobial agent is critical to maintain food quality and safety. A rapid release of an antimicrobial agent from film to food surface may reduce the success of packaging application considerably since this causes subsequent diffusion of the agent from food surface to internal parts which are less critical than the food surface for microbial growth and contamination. On the other hand, if the release rate of the antimicrobial agent is very slow, its inhibitory concentration cannot be reached, consequently, spoilage reactions on the surface may start and food quality and safety can no longer be maintained. Controlled released of the active agent is highly desirable since this helps maintaining inhibitory concentrations of the agent at the critical food surface during storage period (Appendini and Hotchkiss, 2002).

Therefore, incorporation of lauric acid and chitosan into starch based film will be expected to create synergy to enhance the antimicrobial spectrum activity among Gram-positive and Gram-negative bacteria. Kinetics of release for both antimicrobial agents also will study in order to investigate the release mechanism towards both types of bacteria. Besides, incorporation of lauric acid and chitosan into starch based film will strengthen the mechanical properties of starch and improve water permeability of the film.

1.6 Objective of Study

Generally, this study is aiming to develop starch-based packaging film incorporated with chitosan and lauric acid as antimicrobial agents. Therefore, the main objectives of this study are:

1. To formulate and develop an antimicrobial starch-based film in different of starch to chitosan mass ratio.
2. To study and predict on how the polymer matrix structure that being formed from those combination of mixing affect mode of antimicrobial agent release and the effectiveness towards antimicrobial activity, physical and mechanical properties of the film.
3. To investigate on how this mode of release can be controlled to inhibit only the target microorganism.

1.7 Scope of Study

In this study, starch used as packaging material incorporated with lauric acid and chitosan as antimicrobial agents to produce antimicrobial film. Solution of starch and chitosan with different mixing ratios from S:C:LA ratio 1:9:0.08 to S:C:LA ratio: 9:1:0.72 starch/chitosan (w/w) will be blended to formulate the synergy antimicrobial film (AM) using starch, lauric acid and chitosan.

Antimicrobial film formulated then will be characterized based on antimicrobial activity against Gram-positive (*B. subtilis*) and Gram-negative (*E. coli*) bacteria, water barrier properties, mechanical and physical properties. Performance evaluation of physical and mechanical properties focused on water vapour permeability, film strength and water uptake of the film besides other test that support the determination of the physical and mechanical properties of the film. While, evaluation on mechanism of antimicrobial agent release from food simulant was carried out by using mathematical release kinetic model.

1.8 Outline of the Thesis

This thesis consists of 6 Chapters. Chapter 1 introduces the introduction of the research, significance of the study, research problem, the objective and the scope of the study. Chapter 2 presents the literature review on the food packaging and its role in the food chain, active and antimicrobial packaging, antimicrobial agents, spoilage microorganism, and factors affecting the effectiveness of antimicrobial packaging including the control release and release mechanism. Chapter 3 provides a detailed methodology of this research to achieve the targeted objectives. Chapter 4 shows the results and discussion on antimicrobial spectrum activity and lauric acid release behaviour of AM starch-based film while in chapter 5 presents the results and discussion on physical, microstructure and mechanical properties of AM starch-based film formed. Finally chapter 6 summarises the findings of this study and suggestions for further work.

1.9 Published Work

The work has resulted in two papers published in journals, one abstract published in a journal, one paper in review, four papers published in conference proceedings, an oral presentation; two posters presented at conferences, exhibitions and patent. All the publications are listed in Table 1.2 below.

Table 1.2: List of Publications

No	Paper Title	Publication Type	Status
1.	Salleh, E., Muhamad, I. I. and Khairuddin, N. (2007). Preparation, characterization and antimicrobial analysis of antimicrobial starch-based film incorporated with chitosan and lauric acid. Asian Chitin Journal, 3, 55–68.	International Journal	Published
2.	Eraricar Salleh, Ida Idayu Muhamad and	International	Published

	Nozieanna Khairuddin (2009). Structural Characterization and Physical properties of antimicrobial starch-based films. World Academy of Science, Engineering and Technology, 55, 432-440.	Journal	
3.	Eraricar, S., Ida Idayu, M. and Nozieana, K. (2008). Characterization of the mechanical, chemical and thermal properties of antimicrobial (AM) starch-based films. International Journal of Natural Products and Medical Plant Research (Planta Medica), 74:1208.	International Journal	Published
4.	E. Salleh and I.I. Muhamad. Starch-based AM films incorporated with lauric acid and chitosan. American Institute of Physics (AIP). (In review).	International Journal	In review
5.	Salleh, E., Muhamad, I. I. and Khairuddin, N. Inhibition of B. subtilis and E. coli by AM starch-based film incorporated with lauric acid and chitosan. Proceedings of 3rd International Symposium Food and Agricultural Products: Processing and Innovations (CIGR), Naples, Itali (24-26 September 2007).	International conference	Published
6.	Salleh, E., Muhamad, I. I. and Khairuddin, N. Mechanical properties and antimicrobial analysis of AM starch-based film. Proceedings of Polymer Advanced	International conference	Published

	Technologies (PAT2007), Shanghai, China (22-25 October 2007).		
7.	Salleh, E., Muhamad, I. I. and Khairuddin, N. Performance study of lauric acid and chitosan as antimicrobial agents in starch-based film films. Proceedings of 2nd South East Asian Technical University Consortium (SEATUC), ITB Bandung (26-27 February 2008).	International conference	Published
8.	E. Salleh and I. I. Muhamad. Water barrier properties of Starch/chitosan blend films. Proceedings of 4th South East Asian Technical University Consortium (SEATUC) Symposium, Tokyo, Jepun (25-26 February 2010).	International conference	Published
9.	N. Khairuddin, I. I. Muhamad, E. Salleh, D. N. Abang Zaidel, N. A. Zaki. Effects of antimicrobial agent in starch-based films towards inhibition of bacteri. Poster presented at Asian Food Conference 2007, Kuala Lumpur (21-23 August 2007).	International conference	Poster Presentation
10.	E. Salleh and I. I. Muhamad. Mechanical properties of starch/chitosan blend films containing lauric acid. Poster presentation at 3rd International Conference on Chemical and bioprocess Engineering in conjuction with 23rd Symposium of Malaysian Chemical Engineers (Somche 2009), Sabah (12-14 August 2009).	International conference	Poster Presentation

11.	Ida Idayu Muhamad, Eraricar Salleh, Nozieana Khairuddin and Mohd Redza A. Rahman. Intellectual property patent protection PI No: 2007 1577 for "An active packaging using a smart bio-switch concept".	UTM Patent	Patent Pending
12.	Ida Idayu Muhamad, Eraricar Salleh, Nozieana Khairuddin and Mohd Redza A. Rahman. Active - smart plastic films using a bio-switch concept for application in packaging. Salon International Des Inventions, (2007).	International Exhibition Geneva, Switzerland.	Gold Medal
13.	Ida Idayu Muhamad, Eraricar Salleh, Nozieana Khairuddin and Mohd Redza A. Rahman. Active & smart packaging for monitoring safety using a bio-switch concept. Malaysian Technology Expo (MTE), PWTC Kuala Lumpur, (2007).	National Exhibition Kuala Lumpur	Gold Medal
14.	Ida Idayu Muhamad, Eraricar Salleh, Nozieana Khairuddin and Mohd Redza A. Rahman. Active packaging using a smart bio-switch concept. INATEX, UTM Skudai, (2006).	UTM Exhibition	Bronze Medal

REFERENCES

Ahvenainen, R. (2003). *Novel Food Packaging Techniques*. Cambridge, England: Woodhead Publishing Limited.

Ahvenainen, R. and Hurme, E. (1997). Active and Smart Packaging for Meeting Consumer Demands for Quality and Safety. *Food Additives and Contaminants*. 14(6 & 7), 753–63.

Aider, M. (2010). Chitosan Application for Active Bio-Based Films Production and Potential in the Food Industry: Review. *LWT-Food Science and Technology*, 43, 837-842.

Allcock, H. R. and Kellam E. C. (2003) The Synthesis and Applications of Novel Aryloxy /Oligoethyleneoxy Substituted Polyphosphazenes as Solid Polymer Electrolytes. *Solid State Ionics*. 156(3-4), 401-414.

Al-Muhtaseb, A.H., McMinn, W and Magee, T. (2004). Water Sorption Isotherm of Starch Powders Part 1: Mathematical Description of Experimental Data. *Journal of Food Engineering.* 61(3), 297-307.

Andreani, L., Cercena, R., Ramos, B. G. Z. (2009). Development and Characterization of Wheat Gluten Microspheres for Use in a Controlled Release System. *Materials Science and Engineering C.* 29, 524-531.

Anon. (1994). Talking Boxes, Food Temperature Sensors and Other Smart Packaging is Not Far Off. *Quick Frozen Foods International.* 3682, 114.

Appendini, P. and Hotchkiss, J. H. (1996). Immobilization of Lysozyme on Synthetic Polymers for the Application to Food packages. *Book of Abstracts* of 1996 IFT Annual Meeting. 22-26 June. New Orleans, LA, 177.

Appendini, P. and Hotchkiss, J. H. (1997). Immobilization of Lysozyme on Food Contact Polymers as Potential Antimicrobial Films. *Packaging Technology Sciences*. 10(5), 271–9.

Appendini, P. and Hotchkiss, J. H. (2002). Review of Antimicrobial Food Packaging. *Innovative Food Science and Emerging Technologies.* 3, 113-126.

Avachat, A and Kotwal, V. (2007). Design and Evaluation of Matrix-Based Controlled Release Tablets of Diclofenac Sodium and Chondroitin Sulphate. *AAPS Pharmaceutical Sciences Technology*. 8(4) 1-6.

Avadi, M. R., Sadeghi, A. M. M., Tahzibi, A., Bayati, K., Pouladzadeh, M., Zohuriaan-Mehr, M. J. and Rafiee-Tehrani, M. (2004). Dithymethyl Chitosan as An Antimicrobial Agent: Synthesis, Characterization and Antibacterial Effects. *European Polymer Journal*. 40, 1355-1361.

Avella, M., De Vlieger, J. J., Errico, M. E., Fischer, S., Vacca, P. and Volpe, M. G. (2005). Biodegradable Starch/Clay Nanocomposites Films for Food Packaging Applications. *Food Chemistry*. 93, 467-474.

Averbach, B. L. (1978). Film-forming Capability of Chitosan. *Proceeding, First International Conference on Chitin/Chitosan*. 199-209.

Ayranci, F. and Tunc, S. (2003). A Method for the Measurement of the Oxygen Permeability and the Development of Edible Films to Reduce the Rate of Oxidative Reactions in Freshs Foods. *Food Chemistry.* 80, 423-431.

Azeredo, H.M. C., Faria, J. A. F. and Azeredo, A.M. C. (2000). Embalagens Ativas Para Alimentos. *Ciencia e Tecnologia de Alimentos*. 20(3), 337–341.

Balanyk, T. E. and Sandham, H.J. (1985). Development of Sustained-Release Antimicrobial Dental Varnishes. *Journal of Dental Research.* 64, 1356-1360.

Ban, W., Song, J., Argyropoulos, D. S. and Lucia, L. A. (2006). Influence of Natural Biomaterials on the Elastic Properties of Starch-derived Films: An optimization Study. *Industrial and Engineering Chemistry Research*. 45, 627-633.

Bangyekan, D., Aht-Ong and Srikulkit, K. (2006). Preparation and Properties Evaluation of Chitosan-Coated Cassava Starch Films. *Carbohydrate Polymers.* 63, 61-71.

Bastarrachea, L., Dhawan, S., Sablani, S. S. and Powers, J. (2010). Release Kinetics of Nisin from Biodegradable Poly(butylenes adipate-co-terephthalate) Films into Water. *Journal of Food Engineering*. 100, 93-101.

Bell, L. and Touma, D. (1996). Glass Transition Temperatures Determined Using a Temperature-Cycling Differential Scanning Calorimeter. *Journal of Food Science*. 61 (4), 807-810.

Berg, M. C., Zhai, L., Cohen, R. E. and Rubner, M. F. (2006). Controlled Drug Released from Porous Polyelectrolyte Multilayers. *Biomacromolecules.* 7, 357-364.

Bertuzzi, M. A., Vidaurre, E. F. C., Armada, M. and Gottifredi, J. C. (2007). Water Vapor Permeability of Edible Starch Based Films. *Journal of Food Engineering*. 80, 972-978.

Beuchat, L. R and Golden, D. A. (1989). Antimicrobial Occurring Naturally in Foods. *Food Technology*. 43, 134-142.

Bezemer, J. M., Radersma, R., Grijpma, D. W., Dijkstra, P. J., Feijen, J. and Van Blitterswijk, C. A. (2000). Zero-order Release of Lysozyme from

Poly(ethylene glycol) /Poly(butylene terephthalate) Matrices. *Journal of Controlled Released.* 64, 179-192.

Blackburn, C. (2006). *Food Spoilage Microoranisms*. Unilever Research Colworth,UK: Wodhead Publishing.

Bourtoom, T and Chinnan, M. S. (2008). Preparation and Properties of Rice Starch-Chitosan Blend Biodegradable Film. *LWT-Food Science and Technology*. 41, 1633-1641.

Branen, J. K., and Davidson, P. M. (2004). Enhancement of Nisin, Lysozyme, and Monolaurin Antimicrobial Activities by Ethlenediamenetetraacetic Acid and Lactoferrin. *International Journal of Food Microbiology*. 90, 63-74.

Brayden, D. J. (2003). Controlled Release Technologies for Drug Delivery. *Drug Discovery Today*. 8, 976.

Brody, A. K., Strupinsky, E. R. and Kline, L. R. (2001). *Active Packaging for Food Applications*. USA: CRC Press.

Buonocore, G. G., Del Nobile, M. A., Panizza, A., Corbo, M. R. and Nicolais, L. (2003). A General Approach to Describe the Antimicrobial Agent Release from Highly Swellable Films Intended for Food Packaging Applications. *Journal of Controlled Release*. 90, 97-107.

Butler, B., Vergano, P. and Testin, R. (1996). Mechanical and Barrier Properties of Edible Chitosan Films as Affected by Composition and Storage. *Journal of Food Science.* 61, 953-955.

Byrme, G. (1997). Intelligent Packaging. *Product and Image Security.* 1(3), 21–2.

Callegarin, F., Quezada Gallo, J. A., Debeaufort, F. and Voilley, A. (1997). Lipids and Biopackaging. *Journal of the American Oil Chemist Society*. 74, 1183-1192.

Caner, C., Vergano, P. and Wiles, J. (1998). Chitosan Film Mechanical and Permeation Properties as Affected by Acid, Plastisizer and Storage. *Journal of Food Science*. 63, 1049-1053.

Caner, C. (2005). The Effect of Edible Eggshell Coatings on Egg Quality and Consumer Perception. *Journal of the Science of Food and Agriculture.* 85 (11), 1897-1902.

Cao, N., Fu, Y., He, J. (2007). Mechanical Properties of Gelatin Films Cross-linked, Respectively, by Ferulic Acid and Tannin Acid. *Food Hydrocolloids.* 21, 575–584.

Cha, D. S., Choi, J. H., Chinnan, M. S. and Park, H. J. (2002). Antimicrobial Films Based on Na-alginate and κ-carrageenan. *Labensmittel Wissenschaft und Technologie*. 35 (8), 715-719.

Chandra, R. and Rustgi, R. (1998). Biodegradable Polymers. *Progress in Polymer Science.* 23, 1273-1335.

Chen, J., Liu, C., Chen, Y., Chen, Y and Chang, P. R. (2008). Structural Characterization and Properties of Starch/konjac glucomannan Blend Films. *Carbohydrate polymers*. 74, 946-952.

Chen, M. C., Yeh, G. H. C. and Chiang B. H. (1996). Antimicrobial and Physicochemical Properties of Methyl Cellulose and Chitosan Films Containing a Preservative. *Journal of Food Processing and Preservation*. 20, 279-390.

Chillo, S., Flores, S., Mastromatteo, M., Conte, A., Gerschenson, L. and Del Nobile, M. A. (2008). Influenced of Glycerol and Chitosan on Tapioca Starch-Based Edible Film Properties. *Journal of Food Engineering*. 88(2), 159-168.

Choi, J. H., Choi, W. Y., Cha, D. S., Chinnan. M. J., Park, H. J., Lee. D. S. and Park, J. M (2005). Diffusivity of Potassium Sorbate In κ-Carrageenan Based Antimicrobial Film. LWT. 38, 417-423.

Chung, D. Papadakis, S. E. and Yam, K. L. (2001). Release of Propyl Paraben from a Polymer Coating into Water and Food Simulating Solvents for Antimicrobial Packaging Applications. *Journal of Food Protection*. 25, 71-87.

Chung, D., Papadakis, S. E. and Yam, K. L. (2002). Evaluation of a Polymer Coating Containing Triclosan as the Antimicrobial Layer for Packaging materials. *International Journal of Food Science and Technology*. 38, 165-169.

Coma, V., Sebti, I., Pardon, P., Deschamps, A. and Pichavant, H. (2001). Antimicrobial Edible Packaging Based on Cellulosic Ethers, Fatty Acids and Nisin incorporation to inhibit *Listeria innocua* and *Staphylococcus aureus*. *Journal of Food Protection.* 64 (4), 470-475.

Comyn, J. (1985). *Polymer Permeability*. Dordrecht, The Netherlands: Kluwer Academic Publishers.

Cooksey, D. K., Gremmer, A. and Grower, J. (2000). Characteristics of Nisin Containing Corn Zein Pouches for Reduction of Microbial Growth in Refrigerated Shredded Cheddar cheese. *2000 IFT Annual Meeting Book of Abstracts.* Chicago, IL: Institute of Food Technologists. 188.

Cooksey, K. (2001). Antimicrobial Food Packaging. *Food, Cosmetics and Drug Packaging*. 24(7), 133–7.

Crank, J. (1956). *The Mathematics of Diffusion*. New York : Oxford University Press. 12-15

Crouch, A. A., Seow, W. K., Whitman, L. M and Thong, Y. H. (1991). Effect of Human Milk and Infant Milk Formulae on Adherence of *Giardia intestinalis*. *Transactions of the Royal Society of Tropical Medicine and Hygiene*. 85, 617-619.

Cuq, B., Gontard, N., Aymard, C. and Guibert, S. (1997). Relative Humidity and Temperature Effects on Mechanical and Water Vapor Barrier Properties of Myofibrillar Protein-Based Films. *Polymer Gels and Network*. 5(1), 1-15.

Cutter, C. N. (2006). Opportunities for Bio-Based Packaging Technologies to Improve the Quality and Safety of Fresh and Further Processed Muscle Foods. *Meat Science*. 74, 131-142.

Daeschul, M. A. (1989). Antimicrobial Substances from Lactic Acid Bacteria for Use as Food Preservatives. *Journal of FoodTechnology*. 43(1), 164-167.

Das, E. (2004). *Effect of Controlled Atmosphere Storage,Modified Aatmosphere Packaging and Gaseous Ozone Treatment on the Survival Characteristics of Salmonella enteritidis at Cherry Tomatoes*. Master Thesis. Middle East Technical University, Turkey.

Dash, V., Mishra, S. K., Singh, M., Goyal, A. K. and Rath, G. (2010). Release Kinetic Studies of Aspirin Microcapsules from Ethyl Cellulose, Cellulose Acetate Phthalate and their Mixtures by Emulsion Solvent Evaporation Method. *Scientica Pharmaceutica*. 78, 93-101.

Dawson, P. L., Hoffman, K., and Han, I. Y. (2000). Biocide-Impregnated Food Films to Inhibit Food Pathogens. *Second NSF International Conference on Food Safety*. October. Savannah, GA. 11-13.

Dawson, P. L., Carl, G. D., Acton, J. C. and Han I. Y. (2002). Effect of Lauric acid and Nisin-impregnated Soy-based Films on the Growth of *Listeria Monocytogenes* on Turkey Bologna. *Poultry Science*. 81, 721-726.

Dawson, P. L., Harmon, L., Sotthibandhu, A. and Han, I. Y. (2005). Antimicrobial Activity of Nisin-adsorbed Silica and Corn Starch Powders. *Journal of Food Microbiology*. 22 (1), 93-99.

Day, B. P. F. (2000). Intelligent Packaging for Foodstuffs. *Food, Cosmetics and Drug Packaging.* 23(12), 233–9.

De Kruijf, N., Van Beest, M., Rijk, R., Sipilainen-malm, T., Paseiro, L. and De Meulenaer, B. (2002). Active and Intelligent Packaging: Applications and Regulatory Aspects. *Food Additives and Contaminants.* 19, 144–62.

Del Nobile, M. A., Conte, A., Incoronato, A. L. and Panza, O. (2008). Antimicrobial Efficacy and Release Kinetics of Thymol from Zein Films. *Journal of Food Engineering*. 89, 57-63.

Devlieghere, F., Vermeiran, L., and Debevere, J. (2004). New Preservartion Technologies: Possibilities and Limitations. *International Dairy Journal*. 14, 273-285.

Dobias, J., Chudackova, K., Voldrich, M. and Marek, M. (2000). Properties of Polyethylene Films with Incorporated Benzoic Anhydride and/or Ethyl and Propyl Esters of 4-Hydroxybenzoic Acid and Their Suitability for Food Packaging. *Food Additives and Contaminants*. 17(12): 1047-1053

Dodane, V. and Vilivalam, V. D. (1998). Pharmaceutical Applications of Chitosan. *Pharmaceutical Science & Technology Today*. 1 (6), 246-253.

Duanmu, J., Gamstedt, E. K. and Rosling, A. (2007). Hydromechanical Properties of Composites of Crosslinked Allyglycidyl-ether Modified Starch Reinforced by Wood Fiber. *Journal of Composites Science and Technology*. 67, 3090-3097

Dutta, P. K., Tripathi, S., Mehrotra, G. K. and Dutta, J. (2009). Perspectives for Chitosan Based Antimicrobial Films in Food Application. *Food Chemistry*. 114, 1173-1182

Enig, M. G. (1998). Lauric oils as Antimicrobial Agents: Theory of Effect, Scientific Rationale and Dietary Applications as Adjunct Nutritional Support for HIV-Infected Individuals. In Watson, R. R. (Ed). *Nutrients and Foods in AIDS* (pp. 81-97). Boca Raton: CRC Press.

Espert, A., Vilapna, F. and Karlsson, S. (2004). Comparison of Water Absorption in Natural Cellulosic Fibres from Wood and One-Year Crops in Polypropylene Composites and its Influence on Their Mechanical Properties. *Composites Part A: Applied Science and Manufacturing*. 35(11), 1267-1276.

Fama, L., Rojas, A. M., Goyanes, S., and Gerschenson, L. (2005). Mechanical Properties of Tapioca-Starch Edible Films Containing Sorbates, *LWT-Food Science and Technology*. 38 (6), 631–639.

Fang, J. M, Fowler, P. A, Tomkinson, J, Hill, C. A. S (2002). The Preparation and Characteristic of a Series of Chemically Modified Potato Starches. *Carbohydrate Polymer*. 47, 245-252.

Fernandez, C. M., Karjalainen, M., Airaksinen, S, Rantanen,J., Krogars, K. and Yliruusi, J. (2004). Physical Stability and Moisture Sorption of Aqueous Chitosan-Amylose Starch Films Plastisized with Polyols. *European Journal of Pharmaceutics and Biopharmaceutics*. 58, 69-76.

Fernandez-Saiz, P., Lagaron, J. M., Hernandez-Muñoz, P. and Ocio, M. J. (2008). Characterization of Antimicrobial Properties on the Growth of *S. aureus* of Novel Renewable Blends of Gliadins and Chitosan of Interest in Food Packaging and Coating Applications. *International Journal of Food Microbiology*. 124 (1), 13-20.

Fernandez-Saiz, P., Lagaron, J. M. and Ocio, M. J. (2009). Optimization of the Biocide Properties of Chitosan for its Application in the Design of Active Films of Interest in the Food Area. *Food Hydrocolloids*. 23: 913-921.

Finkenstadt, V. L. and Willet, J. L. (2004). A Direct-current Resistance Technique for Determining Moisture Content in Native Starches and Starch-based Plasticized Materials. *Carbohydrate Polymers*. 55, 149-154.

Fletcher, R. D., Albers, A. C., Albertson, J. N. and Kabara, J. J. (1985). Effects of Monoglycerides on Mycoplasma Pneumoniae Growth. In Kabara, J.J. (Ed.). *The Pharmacological Effect of Lipids II*. (pp. 59-63). Champaign Illinois: American Oil Chemists' Society.

Floros, J. D., Dock, L. L. and Han, J. H. (1997). Active Packaging Technologies and Applications. *Food, Cosmetics and Drug Packaging*. 20(1), 10–17.

Forssell, P., Lahtinen, R., Lahelin, M. and Myllarinen, P. (2002). Oxygen Permeability of Amylose and Amylopectin Films. *Carbohydrate Polymers.* 47, 125-129.

Franssen, L. R. and Krochta, J. M. (2003). Edible Coatings Containing Natural Antimicrobial for Processed Foods. In Soller, S. (Ed). *Naturals Antimicrobials for the Minimal Processing of Foods*. Boca Raton, FL, USA: CRC Press.

Freddi, G., Romano, M., Massafra, M. R. and Tsukada, M. J. (1995). Chitosan/Gelatin Scaffolds Obtained by Soft Lithograpy. *Journal of Applied Polymer Science*. 56, 1537-1545.

Friedman, M., Henika, P. R., Levin, C. E. and Mandrell, R. E. (2004). Antibacterial Activities of Plant Essential Oils and Their Components against *Escherichia Coli* 0157:H7 and *Salmonella Entrice* in Apple Juice. *Journal of Agricultural and Food Chemistry*. 52, 6042-6048.

Funke, U., Bergthaller, W. and Lindhauer, M. G. (1998). Processing and Characterization of Biodegradable Products Based on Starch. *Polymer Degradation and Stability*. 59 (1-3), 293-296.

García, L. R., Abriouel, H., Ben, O. N., Pérez, R. and Grande, M. J. (2004). Antimicrobial Activity of Enterocin EJ97 against *Bacillus macroides/B. maroccanus* isolated from Zucchini Purée. *Journal of Applied Microbiology*. 97 (4), 731–737.

Garcia, M., Martino, M and Zaritizky N. (2000). Lipid Addition to Improve Barrier Properties of Edible Starch-Based Films and Coatings. *Journal of Food Sciences*. 65(6), 941-947.

Garcia, M., Pinotti, A., Martino, M. N. and Zaritzky, N. E. (2009). Characterization of Starch and Composites Edible Film Coating. *Edible Film and Coating for Food Application. 169 – 170.*

Gemili, S (2007). Preparation and Characterization of Antimicrobial Polymeric Films for Food Packaging Applications. Master thesis. *School of Engineering and Science of İzmir Institute of Technology*.

Gemili, S., Yemenicioğlu, A. and Altinkaya, S. A. (2009). Development of Cellulose Acetate Based Antimicrobial Food Packaging Materials for Controlled Release of Lysozyme. *Journal of Food Engineering*. 90, 453-462.

Gennadios, A., Weller, C. L. and Testin, R. F. (1993). Temperature Effect on Oxygen Permeability of Edible Protein-based Films. *Journal of Food Science*. 58, 212-219.

Ghosh, R. N., Jana, T., Ray, B. C. and Adhikari, B. (2004). Grafting of Vinyl Acetate onto Low Density Polyethylene-Starch Biodegradable Films for Printing and Packaging Applications. *Polymer International*. 53, 339-343.

Gill, A. O. (2000). *Application of Lysozyme and Nisin to Control Bacterial Growth on Cured Meat Products.* M.Sc. Dissertation. The University of Manitoba.

Glenn, G. M. and Hsu, J. (1997). Compression-formed Starch-based Plastic. *Industrial Crops and Products*. 7 (1), 37-44.

Gomes, M. E., Ribeiro, A. S., Malafaya, P. B., Reis, R. L. and Cunha, A. M. (2001). A New Approach Based on Injection Moulding to Produce Biodegradable Starch-Based Polymeric Scaffolds: Morphology, Mechanical and Degradation Behaviour. *Journal of Biomaterials*. 22 (9), 883-889.

Gontard, N., Guilbert, S. and Cuq, J. L. (1992). Edible Wheat Gluten Films: Influence of Main Process Variables on Films Properties Using Response Surface Methodology. *Journal of Food Science.* 57, 190-199.

Gontard, N., Marchesseau, S., Cuq, J. L. and Guilbert, S. (1995). Water vapor Permeability of Edible Bilayer Films of Wheat Gluten and Lipids. *International Journal of Food Science and Technology*. 30, 49-56.

Gram, L., Ravn, L., Rasch, M., Bruhn, J. B, Christensen, A. B. and Givskov, M. (2002). Food Spoilage-Interactions between Food Spoilage Bacteria. *International Journal of Food Microbiology.* 78, 79-97.

Greener, I. K. and Fennema, O. (1989a). Barner Properties and Surface Characteristics of Edible Bilayer Films. *Journal of Food Science*. 54, 1393-1399.

Greener, I. K. and Fennema, O. (1989b). Evaluation of Edible, Bilayer Films for Use as Moisture Barriers for Food. *Journal of Food Science*. 54, 1400-1406.

Guilbert, S. and Biquet, B. (1996). Edible films and Coatings. *Food Packaging Technology*. 1, 315-353.

Halek, G. W. and Garg, A (1989). Fungal Iinhibition by a Fungicide Coupled to an Ionomeric Film. *Journal of Food Safety*. 9, 215-222.

Halendar, I. A., Nurmiaho-Lassila, E. L., Ahvenainen, R., Rhoades, J. and Roller, S. (2001). Chitosan Disrupts the Barrier Properties of the Outer Membrane of Gram-Negative Bacteria. *International Journal of Food Microbiology*. 71, 235-244.

Han, J. H. (1996). *Modeling the Inhibition Kinetics and the Mass Transfer of Controlled Releasing Potassium Sorbate to Develop an Antimicrobial Polymer for Food Packaging*. Phd. Thesis. Purdue University.

Han, J. H. (2000). Antimicrobial Food Packaging. *Food Technology***.** 54(3), 56–65.

Han, J. H. (2001). Design Edible and Biodegradable Films/coatings Containing Active Ingredients. In Park, H. J, Testin, R.F, Chinnan, M.S. and Park, J.W. (Eds). *Active Biopolymer Films and Coatings for Food and Biotechnological Uses*. Proceedings of Pre-congress Short Course of IUFoST (April 21–22, 2001, Seoul, Korea), 187–98.

Han, J. H. (2002). Protein-based Edible Films and Coatings Carrying Antimicrobial Agents in Gennadios, A. (Ed). *Protein-based Films and Coatings* (pp 485-99). Boca Raton, FL, CRC Press.

Han, J. H. (2003a). Design of Antimicrobial Packaging Systems. *International Review of Food Science and Technology*. 11, 106-109.

Han, J. H. (2003b). Antimicrobial Food Packaging. In Ahvenainen, R. (Ed). *Novel Food Packaging Techniques* (pp. 69-84). Cambridge, England: Woodhead Publishing Limited.

Han, J. H. (2005). *Innovations in Food Packaging*. New York: Academic Press.

Han, J. H. and Floros, J. D. (1997). Casting Antimicrobial Packaging Films and Measuring Their Physical Properties and Antimicrobial Activity. *Journal of Plastic Film and Sheeting*. 13, 287–98.

Han J. H. and Floros, J. D. (1998). Potassium Sorbate Diffusivity in American Processed and Mozzarella Cheeses. *Journal of Food Science.* 63, 435–437.

Han, J. H, and Moon, W. S (2002). Plastic Packaging Materials Containing Chemical Antimicrobial Agents. In Han, J H. (Ed). *Active Food Packaging* (pp. 11-14). Winnipeg,Canada: SCI Publication and Communication Services.

Han, J. H. and Rooney, M. L. (2002). Active Food Packaging Workshop. *Personal Communication of the Annual Conference of the Canadian Institute of Food Science and Technology (CIFST).* 26 May. Edmonton, Alberta, Canada.

Hayhurst, C. (2003). *E. coli: Epidemics Deadly Diseases Throughout History*. New York: Rosen Publishing Group.

Hernell, O., Ward, H., Blackberg, L. and Pereira, M. E. (1986). Killing of *Giardia lamblia* by Human Milk Lipases: An Effect Mediated by Lipolysis of Milk Lipids. *Journal of Infectious Diseases*. 153(7), 15-720.

Higazy, A., Hashem, M., ElShafei, A., Shaker, N. and Hady, M. A. (2010). Development of Antimicrobial Jute Packaging Using Chitosan and Chitosan-Metal. *Carbohydrate Polymers*. 79, 867-874.

Hirano, S., Usutani, A. and Zhang, M. (1994). Chitin Xanthate and Some Xanthate Ester Derivatives. *Carbohydrate Research*. 256(2), 331-336.

Hoffman, K. L., Han, I. Y. and Dawson, P. L. (2001). Antimicrobial Effects of Corn Zein Films Impregnated with Nisin, Lauric Acid, and EDTA. *Journal of Food Protection*. 64(6), 885–9.

Holland, K. T., Taylor, D. and Farrell, A. M. (1994). The Effect of Glycerol Monolaurate on Growth and Production of Toxic Shock Syndrome Toxin-1 and Lipase by *Staphylococcus aureus*. *Journal of Anti-microbial Chemotherapy*. 33, 41-55.

Hong, S. I., Park, J. D. and Kim, D. M. (2000). Antimicrobial and Physical Properties of Food Packaging Films Incorporated with Some Natural Compounds. *Food Science Biotechnology*. 9(1), 38–42.

Hornsten, G. (2001). Active Packaging: Immobilized Enzymes Integrated within a Laminate that Remove Oxygen from within the Package. *Proceedings of the 2nd Nordic Foodpack*. 5-7 September. Norconserv, Stavanger, Norway, 11.

Huang, M. J., Watts, J. D. and Bodor, N. (1997). Theoretical Studies of Inclusion Complexes of α- and β-cyclodextrin with Benzoic Acid and Phenol. *International Journal of Quantum Chemistry*. 65 (6), 1135–115.

Hulleman, S. H. D., Janssen, F. H. P. and Feil, H. (1998). The Role of Water During Plasticization of Native Starches. *Polymer*. 39 (10), 2043-2048.

Hurme, E., Sipilainen-malm, T., Ahvenainen, R. and Nielsen, T. (2002). Active and Intelligent Packaging. In Ohlsson and N. Bengtsson (Eds). *Minimal Processing Technologies in the Food Industry* (pp 87-123). Cambridge, England: T. Woodhead Publishing Limited.

Illum, L. (2003). Nasal Drug Delivery—Possibilities, Problems and Solutions. *Journal of Controlled Release*. 87(1-3), 187-198.

Isaacs, C. E. and Schneidman, K. (1991). Enveloped Viruses in Human and Bovine Milk are Inactivated by Added Fatty Acids (FAs) and Monoglycerides (MGs). *FASEB Journal*. 5325: 1288.

Ishigaki, T., Kawagoshi, Y., Ike, M. and Fujita, M. (1999). Biodegradation of a Polyvinyl Alcohol-starch Blend Plastic Film. *World Journal of Microbiology and Biotechnology*. 15 (3), 321-327.

Jaejoon, H. (2006). *Antimicrobial Packaging System for Optimization of Electron Beam Irradiation of Fresh Produce*. Ph.D. Thesis. Texas A&M University.

Jagannath, J. H., Nanjappa, C., Das Gupta, D. K. and Bawa, A. S. (2003). Mechanical and Barrier Properties of Edible Starch-protein-based Films. *Journal of Applied Polymer Science.* 88, 64–71.

Jagannath, J. H., Radhika, M., Nanjappa, C., Murali, H. S., Bawa, A. S. (2006). Antimicrobial, Mechanical, Barrier and Thermal Properties of Starch–casein Based, Neem (Melia azardirachta) Extract Containing Film. *Journal of Applied Polymer Science.* 101(6), 3948-3954.

Jay, J. (1992). *Modern Food Microbiology*. New York: Van Nostrand Reinhold.

Jay, J. M. (2000). *Modern Food Microbiology*.(6th ed). USA: Aspen Publishers, Inc. 343-351

Je, J. K. and Kim, S. K. (2006). Chitosan Derivatives Killed Bacteria by Disrupting the Outer and Inner Mambrane. *Journal of Agricultural and Food Chemistry*. 54, 6629-6633.

Jeon, Y. J., Park, P. J. and Kim, S. K. (2001). Antimicrobial Effect of Chitooligosaccharides Produced by Bioreactor. *Carbohydrate Polymers*. 44, 71-71.

Kabara, J. J. (1978). Fatty Acids and Derivatives as Antimicrobial Agents - A review. In Kabara, J. J. (Ed). *The Pharmacological Effect of Lipids.* (pp 1 – 14). Champaign Illinois: American Oil Chemists' Society.

Kabara, J. J. (1985). Inhibition of Staphylococcus aureaus. In Kabara, J.J. (Ed). *The Pharmacological Effect of Lipids II.* (pp 71 – 75). Champaign Illinois: American Oil Chemists' Society.

Kabara, J. J. (1993). Medium-chain Fatty Acids and Esters. (2nd Ed) In Davidson, P.M. and Branen, A. L. (Eds). *Antimicrobials in Foods*. (pp 307 – 342). New York: Marcel Dekker.

Kampeerapappun, P., Aht-ong, D., Pentrakoon, D. and Srikulkit, K. (2007). Preparation of Cassava Starch/Montmorillonite Composite Film. *Carbohydrate Polymers*. 67, 155-163.

Kamper, S. L. and Fennema, O. (1984). Water Vapor Permeability of Edible Bilayer Films. *Journal of Food Science*. 49, 1478-1481, 1485.

Kester, J. J. and Fennema, O. (1989). An Edible Film of Lipids and Cellulose Ethers: Barrier Properties to Moisture Vapor Transmission and Structural Evaluation. *Journal of Food Science*. 54, 1383-1389.

KFDA. Korea Food and Drug Administration. (1995). *Food additivers code*. Seoul, Korea: KFDA.

Khor, E. and Lim, L. Y. (2003). Implantable Applications of Chitin and Chitosan. *Journal of Biomaterials*. 24(13), 2339-2349.

Kim, M. and Lee, S. J. (2002). Characteristics of Crosslinked Potato Starch and Starch Filled Linear Low-Density Polyethylene Films. *Journal of Carbohydrate Polymer.* 50, 331-337.

Kim, S., Choi, E. and Cho, Y. I. (1995). The Effect of Header Shapes on the Flow Distribution in a Manifold for Electronic Packaging Applications. *International Communications in Heat and Mass Transfer*. 22(3), 329-341.

Kirby, G. V., Robert K. S. and John M. H. (1977). X-Ray Image Intensifiers. *Advances in Electronics and Electron Physics*. 43, 205-244.

Kitahara, T., Aoyama, Y., Hirakata, Y., Kamihira, S., Konho, S., Ichikawa, N., Nakashima, N., Sasaki, H. and Higuchi, S. (2006). In Vitro Activity of Lauric Acid or Myristylamine in Combination with Six Antimicrobial Agents against Methicillin-Resistant *Staphylococcus Aureus* (MRSA). *International Journal of Antimicrobial Agents*. 27, 51–57.

Klemchuk, P. P. (1990). Degradable Plastics: A Critical Review. *Polymer Degradation and Stability*. 27 (2), 183-202.

Koide, S. S. (1998). Chitin-chitosan: Properties, Benefits and Risks. *Nutrition Research*. 18 (6), 1091-1101.

Koontz, J. L. (2006). Controlled Release of Active Ingredients From Food and Beverage Packaging. *Italian Packaging Technology Award (IPTA) Paper Competition*. 15 February. Blacksburg, VA. 1 – 15.

Krochta, J. M. and De Mulder-Johnston, C. (1997). Edible and Biodegradable Polymer Films: Challenges and Opportunities. *Food Technology*. 51 (2), 61–74.

Kumar, M. N. V. R., Muzzarelli, R. A. A., Muzzarelli, C., Sashiwa, H. and Domb, A. J. (2004). Chitosan Chemistry and Pharmaceutical Perspectives. *Chemical Reviews*. 104, 6017-6084.

Labuza, T. P. and Breene, W. M. (1989). Applications of Active Packaging for Improvement of Shelf-Life and Nutritional Quality of Fresh and Extended Shelf-Life Foods. *Journal of Food Processing and Preservation*. 13, 1.

Lee, C. H., Park, H. J., and Lee, D. S. (2004a). Influence of Antimicrobial Packaging on Kinetics of Spoilage Microbial Growth in Milk and Orange Juice. *Journal of Food Engineering*. 65(4), 527-531.

Lee, C. H., An, D. S., Lee, S. C., Park, H. J. and Lee, D. S. (2004b). A Coating for Use as A Antimicrobial and Antioxidative Packaging Material Incorporating Nisin and α-tocopherol. *Journal of Food Engineering*. 62 (4), 323–329.

Lee, J. W., Kim, S. Y., Kim, S. G., Lee, Y. M., Lee, K. H. and Kim, S. J. (1999). Synthesis and Characteristic of Interpenetrating Polymer Network Hydrogel Composed of Chitosan and Poly(acrylic acid). *Journal Applied Polymer Science.* 73, 113-120.

Li, B., Kennedy, J. F., Peng, J. L., Pie, X. and Xie, B. J. (2006). Preparation and Performance Evaluation of Glucomannan-Chitosan-Nisin Ternary Antimicrobial Blend Film. *Carbohydrate Polymers*. 65, 488-494.

Li, Z., Zhuang, X. P., Liu, F., Guan, .Y. L. and Yao, K. D. (2002). Study on Antibacterial O-Carboxymethylated Chitosan/Cellulose Blend Film from LiCI/N, N-dimethyl-Acetamide Solution. *Polymer*. 43,1541-1547.

Liao,Y. H., Brown, M. B. and Martin, G. P. (2001). Turbidimetric and HPLC Assay for The Determination of Formulated Lysozyme Activity. *Journal of Pharmacy and Pharmacology*. 53, 549–554.

Liu, H., Du, Y. M., Wang, X. H., and Sun, L. P. (2004). Chitosan Kills Bacteria Through Cell Membrane Damage. *International Journal of Food Microbiology*. 95, 147-155.

López-García, B., Veyrat, A., Pérez-Payá, E., González-Candelas, L. and Marcos, J. F. (2003). Comparison of the activity of Antifungal Hexapeptides and the FungisidesTiabendazole and Imazalil Against Postharvest Fungal Phatogens. *InternationalJournal of Food Microbiology*. 89, (2-3).163-170

Lourdin, D., Valle, G. D. and Colonna, P. (1995). Influence of Amylose Content on Starch Films and Foams. *Carbohydrate Polymers.* 27 (4), 261-270.

Lu, D. R., Xiao, C. M. and Xu, S. J. (2009). Starch Based Completely Biodegradable Polymer Materials. *Express Polymer Letters*. 3(6), 366-375.

Madigan, M. and Martinko, J. (2005). *Brock Biology of Microorganisms*. Upper Saddle River, New Jersey: Pearson Prentice Hall.

Mahalik, N. P. and Nambiar, N. M. (2010). Trends in Food Packaging and Manufacturing Systems and Technology. *Trends in Food Science and Technology*. 21, 117-128.

Mali, S. and Grossmann, M. V. E. (2003). Effects of Yam Starch Films on Storability and Quality of Fresh Strawberries. *Journal of Agricultural and Food Chemistry*. 51(24), 7005-7011.

Mali, S., Karam, L. B., Ramos, L. P. and Grossmann, M. V. E. (2004). Relationships Among the Composition and Physicochemical Properties of Starches with the Characteristics of Their Films. *Journal of Agricultural and Food Chemistry.* 52, 7720-7725.

Mali, S., Grossman, M. V. E., Garcia, M. A., Martino, M. N. and Zaritzky, N. E. (2006). Effects on Controlled Storage on thermal, Mechanical and Barrier Properties of Plasticized Films from Different Starch Sources. *Journal of Food Engineering*. 75, 453-460.

Mann, C. M. and Markham, J. L. (1998). A New Method for Determining the Minimum Inhibitory Concentration of Essential Oils. *Journal of Applied Microbiology*. 84, 538-544

Mano, J. F., Koniarova, D. and Reis, R. L. (2003). Thermal Properties of Thermoplastic Starch/Synthetic Polymer Blends with Potential Biomedical Applicability. *Journal of Materials Science: Materials in Medicine*. 14, 127-135.

Maolin, Z., Long, Z., Fumio, Y. and Tamikazu, K. (2004). Study on Antibacterial Starch/chitosan Blend Film Formed under the Action of Irradiation. *Carbohydrate Polymers*. 57, 83-88.

Maruo, B. and Yoshikawa, H. (1989). *Bacillus subtilis: Molecular Biology and Industrial Application.* Tokyo: Elsevier Science Publisher.

Masniyom, P., Benjakul, S. and Viseeanguan, W. (2006). Synergistic Anti microbial Effect of Pyrophosphate on *Listeria monocytogenes* and *Escherichia coli* 0157 in Modified Atmosphere Packaged and Refrigerated Seabass Slices. *LWT-Food Science and Technology*. 39, 302-307.

Mathew, S., Brahmakumar, M. and Abraham, T. E. (2006). Microstructural Imaging and Characterization of the Mechanical, Chemical, Thermal and Swelling Properties of Starch-Chitosan Belend Films. *Biopolymers*. 82, 176-187.

Mathew, S. and Abraham, T. E. (2008) Characterisation of Ferulic Acid Incorporated Starch-Chitosan Blend Films. *Food Hydrocolloids*. 22, 826-835.

Mecitoğlu, C., Yemenicioğlu, A., Arslanoğlu, A., Elmaci, Z. S., Korel, F. and Cetin, A. E. (2006). Incorporation of Partially Purified Hen Egg White Lysozyme into Zeins Films for Antimicrobial Food Packaging. *Food Research International*. 39, 12-21.

Meenakshi, P., Noorjahan, S. E., Rajini, R., Venkateswarlu, U., Rose, C., Sastry, T. P. (2002). Mechanical and Microstructure Studies on the Modification of CA Films by Blending with PS. Bull. *Material Science*. 25, 25-29.

Miller, W. R., Spalding, D. H., Risse, L. A. and Chew, V. (1984). The Effects of an Imazalil-impregnated Film with Chlorine and Imazalil to Control Decay of Bell Peppers. *Proceeding of the Florida State Horticultural Society*. 97, 108–11.

Miranda, S. P., Garnica, O., Lara-Sagahon, V. and Cardenas, G. (2004). Water Vapor Permeability and Mechanical Properties of Chitosan Composite Films. *Journal of the Chilean Chemical Society*. 49, 173-178.

Morillon, V., Debeaufort, F., Capelle, M., Blond, G., and Voilley, A. (2000). Influence of the Physical State of Water on the Barrier Properties of Hydrophilic Films. *Journal Agriculture and Food Chemistry*. 48, 11–16.

Muzzarelli, R. A. A. and Ilari, P. (1994). Chitosans Carrying the Methoxyphenyl Functions Typical of Lignin. *Carbohydrate Polymers*. 23 (3), 155-160.

Nadarajah, D., Han, J. H and Holley, R. A. (2002). Use of Allyl Isothiocyanate to Reduce *Escherichia coli* O157:H7 in Packaged Ground Beef Patties, in *Book of Abstracts of IFT Annual Meeting*. Institute of Food Technologists, Chicago. 249.

Nakamura, E. M., Cordi, L., Almeida, G. S. G., Duran, N. and Mei, L. H. I. (2005). Study and Development of LDPE/ Starch Partially Biodegradable. Compounds. *Journal of Materials Processing Technology*. 236-241.

Nakano, M. M. and Zuber, P. (1998). Anaerobic Growth of a "strict aerobe" (*Bacillus Subtilis*)". *Annual Review of Microbiology*. 52: 165-90.

Nam, S., Han, J. H., Scanlonm, G. and Izydorczyk, M. S. (2002). Use of Extruded Pea Starch Containing Lysozyme as an Antimicrobial and Biodegradable Packaging, in *Book of Abstracts* (2002 IFT Annual Meeting). Chicago, Institute of Food Technologists, 248.

Napierala, D. M. and Nowotarska, A. (2006). Water Vapour Transmission Properties of Wheat Starch-Sorbitol Film. *Acta Agrophysica*. 7(1), 151-159.

Narayan, R. (2001). Drivers for Biodegradable/Compostable Plastics and Role of Composting in Waste Management and Sustainable Agriculture.

Bioprocessing of Solid Waste and Sludge. 1(1). 1-9. Orbit Association Publication.

No, H. K., Park, N. Y., Lee, S. H. and Meyers, S. P. (2002). Antibacterial Activity of Chitosans and Chitosan Oligomers with Different Molecular Weights. *International Journal of Food Microbiology*. 74 (1-2), 65-72.

No, H. K., Park, N. Y., Lee, S. H. and Meyers, S. P. (2003). Comparison of Physicochemical, Binding and Antibacterial Properties of Chitosans Prepared without and with Deproteinization Process. *Journal of Agricultural Food Chemistry*. 51, 7659-7663.

Oh, D. H. and Marshall, D. L. (1993). Antimicrobial Activity of Ethanol, Glycerol Monolaurate or Lactic acid against *Listeria monocytogenes*. *International Journal of Food and Microbiology*. 20, 239-246.

Okada, M. (2002). Chemical Syntheses of Biodegradable Polymers. *Progress in Polymer Science*. 27, 87-133.

Otey, F. H., Westhoff, R. P. and Doane, W. M. (1980). Starch-based Blown Films. *Industrial & Engineering Chemistry Product Research and Development.* 19 (4), 592-595.

Ouattara, B., Simard, R. E., Piette, G., Bégin, A. and Holley, R. A. (2000a). Diffusion of Acetic and Propionic Acids from Chitosan-Based Antimicrobial Packaging Films. *Journal Food Science*. 65(5), 768–773.

Outtara, B., Simard, R. E., Piette, G., Bégin, A. and Holley, R. A. (2000b). Inhibition of Surface Spoilage Bacteria in Processed Meats by Application of Antimicrobial Films Prepared with Chitosan. *International Journal of Food Microbiology*. 62, 139-148.

Ozdemir, M. and Floros, J. D. (2004). Active Food Packaging Technologies. *Critical Reviews in Food Science and Nutrition*. 44, 185-193.

Padgett, T. R., Han, I. Y. and Dawson, P. L. (1998). Incorporation of Food-grade Antimicrobial Compounds into Biodegradable Packaging Films. *Journal of Food Protection.* 61(10), 1330-1335.

Padgett, T. R., Han, I. Y. and Dawson, P. L. (2000). Effect of Lauric Acid Addition on the Antimicrobial Efficacy and Water Permeability of Protein Films Containing Nisin. *Journal of Food Processing and Preservation*. 24, 423-432.

Papadokostaki, K. G., Amarantos, S. G. and Petropoulos, J. H. (1997). Kinetics of Release of Particulate Solutes Incorporated in Cellilosic Polymer Matrices as a Function of Solute Solubility and Polymer Swellability. I. Sparingly Soluble Solutes. *Journal of Applied Polymer Science*. 61**,** 116-120

Park, H. J., Weller, C. L., Vergano, P. J. and Testin R. F. (1993). Permeability and Mechanical Properties of Cellulose-based Edible Films. *Journal of Food Science.* 58, 1361–1364.

Park, S. I, Daeschel, M. A. and Zhao, Y. (2004). Functional Properties of Antimicrobial Lysozyme-Chitosan Composite Films. *Journal of Food Science*. 69,215-221.

Park, S. Y., Marsh, K. S. and Rhim, J. W. (2002). Characteristics of Different Molecular Weight Chitosan Films Affected by the Type of Organic Solvents. *Journal Food Science.* 67(1), 194-7.

Park, S. Y., Marsh, K. S. and Rhim, J. W. (2002). Characteristics of Chitosan Films as Affected by the Type of Solvent Acid. *Journal of Food Science*. 67, 194–197.

Park, S. Y., Jun, S. T. and Marsh, K. S. (2001). Physical Properties of PVOH/Chitosan-Blended Films Cast from Different Solvents. *Food Hydrocolloids*. 15, 499-502.

Park, J. W., Testin, R. F., Park, H. J., Vergano, P. J. and Weller, C. L. (1984). Fatty Acid Concentration Effect on Tensile Strenght, Elongation and Water Permeability of Laminated Edible Films. *Journal Food Science*. 59, 916-919.

Parra, D. F., Tadini, C. C., Ponce, P. and Lugao, A. B (2004). Mechanical Properties and Water Vapor Tansmission in Some Blends of Cassava Starch Edible Films. *Carbohydrate Polymers.* 58, 475-481.

Pavlath, A. E. and Robertson, G. H. (1999). Biodegradable Polymers vs Recycling: What Are the Possibilities. *Critical Reviews in Analytical Chemistry*. 29(3), 231-241.

Paweena L. (2002). *Development of an Antimicrobial Film for Food Packaging*. Phd. Thesis: Michigan State University.

Petersen, K., Nielsen, P. V., Bertelsen, G., Lawther, M., Olsen, M. E., Nilsson, N. H. and Mortensen, G. (1999). Potential of Biobased Materials for food Packaging. *Trends in Food Science and Technology*. 10, 52-68.

Petersson, M. and Stading, M. (2005). Water Vapour Permeability and Mechanical Properties of Mixed Starch-Monoglyceride Films and Effect of Film Forming Conditions. *Food Hydrocolloids*. 19, 123-132.

Petschow, B. W., Batema, R. P. and Ford, L. L. (1996). Susceptibility of *Helicobacter pylori* to Bactericidal Properties of Medium-chain Monoglycerides and Free Fatty Acids. *Antimicrobial Agents and Chemotherapy*. 40, 302-306.

Pranoto, Y., Rakshit, S. K. and Salokhe, V. M. (2005). Enhancing Antimicrobial Activity of Chitosan Films by Incorporating Garlic Oil, Potassium Sorbate and Nisin. *LWT-Food Science and Technology*. 38, 859-865.

Psomiadou, E., Arvanitoyannis, I., Biliaderis, C. G., Ogawa, H. and Kawasaki, N. (1997). Biodegradable Films Made from Low Density Polyethylene (LDPE), Wheat Starch and Soluble Starch for Food Packaging Applications. Part 2. *Carbohydrate Polymers* 33 (4), 227-242.

Quintavalla, S. and Vicini, L. (2002). Antimicrobial Food Packaging in Meat Industry. *Meat Science*. 62, 373-380.

Rabea, E. I., Badawy, M. E. T., Stevens, C. V., Smagghe, G. and Steurbaut, W. (2003). Chitosan as Antimicrobial Agent: Applications and Mode of Action. *Biomacromolecules*. 4, 1457-1465.

Rao, M. S., Chander, R. and Sharma, A. (2008). Synergistic Effect of Chitooligosaccharides and Lysozyme for Meat Preservation. *LWT- Food Science and Technology*. 41, 1995-2001.

Redl, A., Gontard, N., Guilbert, S. and Petropoulus, J. H. (1996). Determination of Sorbic Acid Diffusivity in Edible Wheat Gluten and Lipid Films. *Journal of Food Science*. 61, 116-120.

Reiner, D. S., Wang, C. S. and Gillin, F. D. (1986). Human Milk Kills Giardia lamblia by Generating Toxic lipolytic Products. *Journal of Infectious Diseases*. 154, 825-832.

Rhim, J. W., Lee, J. H. and Ng, K. W. (2007). Mechanical and Barrier of Biodegradable Soy Protein Isolate-Based Films Coated With Polylactic Acid. *LWT-Food Science and Technology*. 40, 232-238.

Rhoades, J. and Rastall, B. (2000). Chitosan as an Antimicrobial agent. *Food Technology International*. 32-33.

Rhoades, J. and Roller, S. (2000). Antimicrobial Actions of Degraded and Native Chitosan against Spoilage Organisms in Laboratory Media and Foods. *Applied and Environmental Microbiology*. 66(1), 80-86.

Rice, L. B. (1995). The Theoretical Origin of Vancomycin-resistant Enterococci. *Clinical Microbiology Newsletter*. 17 (24), 189-192.

Rinaudo, M. (1999). Influence of Acetic Acid Concentration on the Solubilization of Chitosan. *Polymer*. 40, 7029-32.

Rindlav, A., Hulleman, S. H. D. and Gatenholm, P. (1997). Formation of Starch Films with Varying Crystallinity. *Carbohydrate Polymers*. 36, 25-30.

Rindlav, A., Stading, M., Hermansson, A. M. and Gatenholm, P. (1998). Structure, Mechanical and Barrier Properties of Amylose and Amylopectin Films. *Carbohydrate Polymers*. 36, 217-224.

Rodrigues, E. T. and Han, J. H. (2000). Antimicrobial Whey Protein Films Against Spoilage and Pathogenic Bacteria, in *Book of Abstracts* (2000 IFT Annual Meeting). Chicago, Institute of Food Technologists, 191.

Rodrigues, E. T., Han, J. H. and Holley, R. A. (2002). Optimized Antimicrobial Edible Whey Protein Films against Spoilage and Pathogenic Bacteria, in *Book of Abstracts* (2002 IFT Annual Meeting). Chicago, Institute of Food Technologists, 252.

Rooney, M. L. (1995). Development of active and intelligent packaging systems. In Ahvenainen, R., Mattila-Sandholm, T. and Ohlsson, T. (Eds). *New Shelf-life Technologies and Safety Assessments. VTT Symposium 148.* (pp 75-83). Espoo.

Rosa-Gómez, I. D. L., Olguín, M. T. and Alcántara, D. (2008). Antibacterial Behavior of Silver-Modified Clinoptilolite–Heulandite Rich Tuff on Coliform

Microorganisms from Wastewater in a Column System. *Journal of Environmental Management.* 88 (4), 853-863.

Ryan, K. J. and Ray, C. G. (2004). *Sherris Medical Microbiology, An Introduction to Infectious Disease. (4th ed).* Norwalk, Connecticut: McGraw Hill.

Sagoo, S. K., Board, R. and Roller, S. (2002). Chitosan Potentiates The Antimicrobial Action of Sodium Benzoate on Spoilage Yeasts. *Letters in Applied Microbiology*. 34, 168-172.

Salleh, E., Muhamad, I. I. and Khairuddin, N. (2007). Preparation, Characterization and Antimicrobial Analysis of Antimicrobial Starch-Based Film Incorporated with Chitosan and Lauric Acid. *Asian Chitin Journal*. 3, 55-68.

Salleh, E., Muhamad, I. I. and Khairuddin, N. (2009). Structural Characterization and Physical Properties of Antimicrobial (AM) Starcb-Based Films. *World Academy of Science, Engineering and Technology*. 55, 432-440.

Sanches-Silva, A., Cruz, J. M., Sendón-García, R., Franz, R. and Paseiro-Losada, P. (2007). Kinetic Migration Studies from Packaging Films into Meat Products. *Meat Science*. 77, 238-245.

Sands, J. A., Auperin, D. D., Landin, P. D., Reinhardt, A. and Cadden, S. P. (1978). Antiviral Effects of Fatty Acids and Derivatives: Lipid-containing Bacteriophages as a Model System. In Kabara, J.J. (Ed). *The Pharmacological Effect of Lipids*. (pp 75 – 95). Champaign IL: American Oil Chemists' Society.

Sangsuwan, J., Rattanapanone, N. and Rachtanapun, P. (2008). Effect of Chitosan/Methyl Cellulose Films on Microbial and Quality Characteristics of Fresh-cut Cantaloupe and Pineapple. *Postharvest Biology and Technology*. 49, 403-410.

Sanjurjo, K., Flores, S., Gerschenson, L. and Jagus, R. (2006). Study of the Performance of Nisin Supported in Edible Films. *Food Research International*. 39, 749-754.

Sankalia, M. G., Mashru, R. C., Sankalia, J. M. and Sutariya, V. B. (2007). Reversed Chitosan-Aalginate Polyelectrolyte Complex for Stability Improvement of Alpha-amylase: Optomization and Physicochemical Characterization. *Europen Jurnal of Pharmaceutics and Biopharmaceutics*. 65, 215-232.

Santiago-Silva, P., Soares, N. F. F., Brega, J. E., Junior, M. A. W., Barbosa, K. B. F., Volp, A. C. P., Zerdas, E. R. M. A. and Wurlitzer, N. J. (2009). Antimicrobial Efficiency of Film Incorporated with Pediocin (ALTA ® 2351) on Preservation of Sliced Ham. *Food Control*. 20, 85-89.

Scott, G. (2000). Green Polymers. *Polymer Degradation and Stability*. 68, 1-7.

Sebti, I., Broughton, J. L. and Coma, V. (2003). Physicochemical Properties and Bioactivity of Nisin-Containing Cross-Linked Hydroxypropylmethylcellulose Films. *Journal Agriculture Food Chemical*. 51, 6468-6474.

Sen, A. and Bhattacharya, M. (2000). Residual Stresses and Density Gradient in Injection Molded Starch/Synthetic Polymer Blends. *Journal of Polymer*. 41 (26),9177-9190.

Seydim, A. C. and Sarikus, G. (2006). Antimicrobial Activity of Whey Protein Based Edible Films Incorporated with Oregano, Rosemary and Garlic Essential oils. *Food Research International.* 39, 639 – 644.

Shahidi, F., Arachchi, J. K. V. and Jeon, Y. J. (1999). Food Application of Chitin and Chitosans. *Trends in Food Science and Technology*. 10: 37-51.

Shellhammer, T. H. and Krochta, J. M. (1997). Whey Protein Emulsion Film Performance as Affected by Lipid Type and Amount. *Journal of Food Science*. 62, 390-394.

Shigemasa, Y., Saito, K., Sashiwa, H. and Saimoto, H. (1994). Enzymatic Degradation of Chitins and Partially Deacetylated Chitins. *International Journal of Biological Macromolecules.* 16(1), 43-9.

Siepmann, J. and Peppas, N. A. (2001). Modeling of Drug Release from Delivery Systems Based on Hydroxypropyl Methylcellulose (HPMC). *Advanced Drug Delivery Reviews.* 48 (23), 139–157.

Smolander, M., Hurme, E. and Ahvenainen, R. (1997). Leak Indicators for Modified-Atmosphere Packages. *Trends in Food Science and Technology*. 8(4), 101–6.

Smolander, M. (2000). Principles of Smart Packaging. *Packaging Technolog*y. 9–12.

Sofos, J. N., Beuchat, L.R., Davidson, P. M. and Johnson, E. A. (1998). Naturally Occurring Antimicrobials in Food. *Regulatory Toxicology and Pharmacology*. 28(2), 71 – 72.

Sothornvit, R and Pitak, N. (2007). Oxygen Permeability and Mechanical Properties of Banana Films. *Food Research International*. 40, 365-370.

Srinivasa, P. C., Revathy, B., Ramesh, M. N., Harish Prashanth, K. V. and Tharanathan, R. N. (2002). Storage Studies of Mango Packed Using Biodegradable Chitosan Films. *European Food Research and Technology*. 215, 504-508.

Srinivasa, P. C., Ramesh, M. N. and Tharanathan, R. N. (2007). Effect of Plastisizers and Fatty Acids on Mechanical and Permeability Characteristics of Chitosan Films. *Food Hydrocolloids*. 21, 1113-1122.

Stevens, M. P. *(*1999). *Polymer Chemistry*: An Introduction. New York: Oxford University Press. 551 .

Sudarshan, N. R., Hoover, D. G. and Knorr, D. (1992). Antibacterial Action of Chitosan. *Food Biotechnology*. 6 (3), 257-272.

Sun, C. Q., O' Connor, C. J. and Roberton, A. M. (2002). The Antimicrobial Properties of Milkfat after Partial Hydrolysis by Calf pregastric Lipase. *Chemico-Biological Interactions*. 140 (2), 185 - 198.

Suppakul, P., Miltz, J., Sonneveld, K. and Bigger, S. W. (2003). Active Packaging Technologies with an Emphasis on Antimicrobial Packaging and its Applications. *Journal of Food Science*. 68(2), 408-418.

Suppakul, P., Sonneveld, K., Bigger, S. W. and Miltz, J. (2008). Efficacy of Polyethylene- based Antimicrobial Films Containing Principal Constituents of Basil. *LWT-Food Science and Technology*. 41, 779-788.

Takaeuchi, K, and Yuan, J (2002), Packaging Tackles Food Safety: A look at Antimicrobials, Industrial Case Study. *IFT Annual Meeting.* 15–19 June. Anaheim, CA).

Talja, R. A., Helen, H., Roos, Y. H. and Jouppila, K. (2007). Effect of Various Polyols and Polyol Contents on Physical Properties of Potato Starch-Based Films. *Carbohydrate Polymers*. 67(3), 288-295.

Talja, R. A., Helen, H., Roos, Y. H. and Jouppila, K. (2008). Effect of Binary Polyol Mixtures on Physical and Mechanical Properties of Starch-Based Edible Films. *Carbohydrate Polymers.* 71, 269-276.

Tanaka, M., Ishizaki, S., Suzuki, T. and Takai, R. (2001). Water Vapor Permeability of Edible Films Prepared from Fish Water Soluble Proteins as Affected by Lipid Type. *Journal of Tokyo University of Fisheries*. 87, 31-37.

Tang, R., Du, Y. and fan, L. (2003). Dialdehyde Starch-Crosslinked Chitosan Films and Their Antimicrobial Effects. *Journal of Polymer Science*. 41, 993-997.

Tharanathan, R. N. (2003). Biodegradable Films and Composite Coatings: Past, Present and Future. *Trends in Food Science and Technology*. 14, 71-78.

Tester, R. F., Karkalas, J. and Qi, X. (2004). Starch-composition, Fine Structure and Architecture. *Journal of Cereal Science*. 39, 151-165

Trezza, T. A. and Krochta, J. M. (2000). Color Stability of Edible Coatings During Prolonged Storage. *Journal Food Science*. 65(7),1166-1169.

Tripathi, S., Mehrotra, G. K. and Dutta, P. K. (2010). Preparation and Physicochemical Evaluation of Chitosan /Poly (Vinyl Alcohol)/ Pectin Ternary Film for Food Packaging Applications. *Carbohydrate Polymers*. 79(3), 711-716.

Tsai, G. J., Su, W. H., Chen, H. C. and Pan, C. L. (2002). Antimicrobial Activity of Shrimp Chitin and Chitosan from Different Treatments and Applications of Fish Preservation. *Fisheries Science*. 68, 170-177.

Van Soest, J. J. G., Hulleman, S. H. D., De Wit, D. and Vliegenthart, J. F. G. (1996). Changes in the Mechanical Properties of Thermoplastic Potato Starch in Relation with Changes in B-type Crystallinity. *Carbohydrate Polymers*. 29 (3), 225-232.

Van Soest, J. J. G. and Borger, D. B.(1997). Structure and Properties of Compression-molded Thermoplastic Starch Materials from Normal and High-amylose Maize starches. *Journal of Applied Polymer Science.* 64 (4), 631-644.

Van Soest, J. J. G. and Kortleve, P. M. (1999). Influence of Maltodextrins on the Structure and Properties of Compression-molded Starch Plastic Sheets. *Journal of Applied Polymer Science*. 74 (9), 2207-2219.

Vargas, M., Albors, A., Chiralt, A. and González-Martínez, C. (2009). Characterization of Chitosan–Oleic Acid Composite Films. *Food Hydrocolloids*. 23 (2), 536-547.

Vartiainen, J., Skytta, E., Enqvist, J. and Ahvenainen, R. (2003). Properties of Antimicrobial Plastics Containing Traditional Food Preservatives. *Packaging Technology and Science*. 16, 223-229.

Vazquez, B., San Roma, J., Peniche, C. and Cohen, M. E. (1997). Polymeric Hydrophilic Hydrogels with Flexible Hydrophobic Chains. Control of the Hydration and Interactions with Water Molecules. *Macromolecules*. 30, 8440-8446.

Vermeiren, L., Devlieghere, F., Beest, M. V., Kruijf, N. D. and Debevere, J. (1999). Developments in the Active Packaging of Foods. *Trends in Food Science and Technology*. 10, 77-86.

Vojdani, F. and Torres, J. A. (1990). Potassium Sorbate Permeability of Methylcellulose and Hydroxypropyl Methylcellulose Coatings: Effect of Fatty Acid. *Journal of Food Science*. 55, 841-846.

Wagner, J. (1989). The advent of smart packaging. *International Journal of Food Engineering*. 14 (10), 11.

Wahab, M. A. E. and Abdou, E. S. (2010). Influence of Starch and Glycerol on the Properties of Chitosan by Positron Annihilation Spectroscopy. *Journal of Apllied Polymer Science.* 116, 2874-2883.

Wan, Y. Z., Luo, H., He, F., Liang, H., Huang, Y. and Li, X. L. (2009). Mechanical. Moisture Absorption and Biodegradation Behaviors of Bacterial Cellulose Fibre reinforced Starch Biocomposites. *Journal of Composites Science and Technology*. 69, 1212-1217.

Weng, Y. M. and Hotchkiss, J. H (1992). Inhibition of Surface Molds on Cheese byPolyethylene Film Containing the Antimycotic Imazalil. *Journal of Food Protection*. 55(5), 367–9.

Weng, Y. M., Chen, M. J. and Chen, W. (1997). Benzoyl Chloride Modified Ionomer Films as Antimicrobial Food Packaging Materials. *International Journal of Food Science & Technology*. 32 (3), 229–234.

Wong, D. W. S., Gastineau, F. A., Gregorski, K. S., Tillin, S. J. and Pavlath, A. E. (1992). Chitosan-lipid Films: Microstructure and Surface Energy. *Journal of Agricultural and Food Chemistry*. 40, 540-544.

Wu, Y. B., Yu, S. H., Mi, F. L., Wu, C. W., Shyu, S. S., Peng, C. K. and Chao, A. C. (2004). Preparation and Characterization on Mechanical and Antibacterial Properties of Chitosan/Cellulose Blends. *Carbohydrate Polymers*. 57, 435-440.

Wu, Y., Geng, F., Peter R. C., Yu, J. and Ma, X. (2009). Effect of Agar on the Microsrtructure and Performance on the Potato Starch Film. *Carbohydrate Polymers*. 76(2), 299-304.

Xu, Y. X., Kim, K. M., Hanna, M. A. and Nag, D. (2005). Chitosan-Starch Composite Film: Preparation and Characterization. *Industrial Crops and Products*. 21, 185-192.

Yahya, M. Z. A, Harun, M. K., Ali, A. M. M., Mohammat, M. F., Hanafiah, M. A. K. M., Ibrahim, S. C., Mustaffa, M., Darus, Z. M. and Latif, F. (2006). XRD and Surface Morphology Studies on Chitosan-Based Film Electrolytes. *Journal of Applied Sciences*. 6(15), 3150-3154.

Yang, J. H., Yu, J. G., Feng, Y. and Ma, X. F. (2007). Study on the Properties of Ethylenebisformamide Plasticized Corn Starch (EPTPS) with Various Original Water Contents of Corn Starch. *Carbohydrate Polymers*. 69, 256-261.

Yin , Y. J., Yao, K. D., Cheng, G. X and Ma, J. B. (1999). Properties of Polyelectrolyte Complex Films of Chitosan and Gelatin. *Polymer International*. 48, 429-433.

Yogesh, M. (2006). *Development of LDPE-Based Antimicrobial Films for Food Packaging.* Msc. Thesis: Victoria University,Australia.

Yoshida, C. M. P., Bastos, C. E. N. and Franco, T. T. (2010). Modelling of Potassium Sorbate Diffusion through Chitosan Films. *LWT-Food Science and Technology*. 43, 584-589.

Yoshihiko, O., Mayumi, S., Takahiro, A., Hiroyuki, S., Yoshihiro, S. and Ichiro, N. (2003). Antimicrobial Activity of Chitosan with Different Degrees of Acetylation and Molecular with Different Degrees of Acetylation and Molecular Weights. *Biocontrol Science.* 8, 25-30.

Yu, L., Dean, K., and Li, L. (2006). Polymer Blends and Composites from Renewable Resources. *Progress in Polymer Science*. 31, 576-602.

Zactiti, E. M. and Kieckbush, T. G. (2009). Release of Potassium Sorbate from Active Films of Sodium Alginate Crosslinked with Calcium Chloride. *Packaging Technology Science*. 22, 349-358.

Zhai , M., Yoshii, F. and Kume, T. (2003). Radiation Modification of Starch- Based Plastic Sheets. *Carbohydrate Polymers*. 52, 311-317.

Zhai , M., Zhao, L., Yoshii, F. and Kume, T. (2004). Study on Antibacterial Starch/ Chitosan Blend Film Formed Under the Action of Irradiation. *Carbohydrate Polymers*. 57, 83-88.

Zheng, L. N. and Zhu, J. F. (2003). Study on Antimicrobial Activity of Chitosan with Different Molecular Weights. *Carbohydrate Polymers*. 54, 527-530.

Zinoviadou, K. G., Koutsoumanis, K. P. and Biliaderis, C. G. (2010). Physical and Thermo-mechanical Properties of Whey Protein Isolate Films Containing Antimicrobials, and Their Effect against Spoilage Flora of Fresh Beef. *Food Hydrocolloids*. 24, 49-59.

Zivanovic, S., Li, J., Davidson, P. M. and Kit, K. (2007). Physical, Mechanical and Antibacterial Properties of Chitosan/PEO Blend Films. *Biomacromolecules.* 8(5), 1505-1510.